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ABSTRACT

The technical subject matter of this rate training manual is written for regular navy and naval reserve personnel. Responsibilities for optical shop administration, supervision, and training are discussed in detail. Metals are studied in connection with heat treating processes. Characteristics of light are analyzed to familiarize students with interference, polarization, and double refraction phenomena. Following discussions of basic theories in construction, step-by-step procedures are described for the disassembly, reassembly, maintenance, and repair of submarine periscopes, ship-mounted binocular Mark 3 Mod 2, turret periscope Mark 20 Mod 6, tilting-prism telescope gunsights, and rangefinders including stereoscopic rangefinder Mark 42 Mod 27. Besides illustrations for explanation use, information on advancement and a training film list are also provided. (CC)

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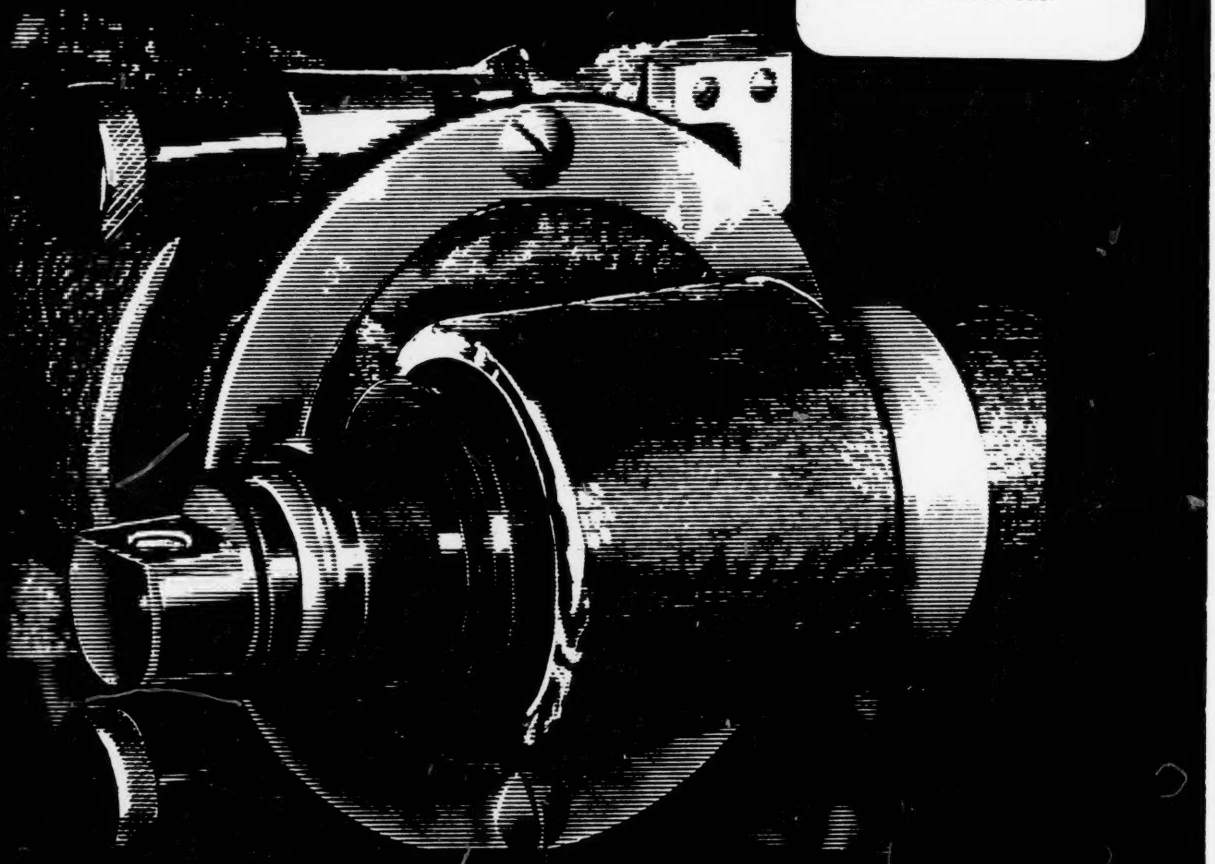

OPTICALMAN 1 & C

BUREAU OF NAVAL PERSONNEL

RATE TRAINING MANUAL

NAVPERS 10206

SE 014 121

PREFACE

This training course was written for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of Opticalman 1 and C. Combined with the necessary practical experience and a thorough study of the related basic Navy Training Courses the information in this course will help the reader prepare for advancement-in-rating examinations.

This Navy Training Course was prepared by the Training Publications Division, Naval Personnel Program Support Activity, Washington, D.C., for the Bureau of Naval Personnel. Material provided by manufacturers is gratefully acknowledged. Technical assistance was provided by the U.S. Naval Schools, Opticalmen, Great Lakes; the Naval Ship Systems Command; and the Naval Ordnance Systems Command.

First Edition 1950
Revised 1966

AS THIS BOOK GOES TO PRESS, THE NAVY HAS UNDERGONE A MAJOR REORGANIZATION IN WHICH CERTAIN BUREAUS HAVE BEEN REDESIGNATED AS SYSTEMS COMMANDS.

CHECK INSTRUCTIONS AND NOTICES FOR FURTHUR INFORMATION CONCERNING THIS CHANGE.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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READING LIST

NAVY TRAINING COURSES

Machinery Repairman 3 & 2, (Chapters 3, 4, 5, 6, 9), NavPers 10530-B

Blueprint Reading and Sketching NavPers 10077-B

Machinery Repairman 1 & C, (Chapter 6), NavPers 10531-A

OTHER PUBLICATIONS

Ordnance Pamphlet 2080

Ordnance Pamphlet 105

Ordnance Pamphlet 1858

Ordnance Pamphlet 2147

Ordnance Pamphlet 2531

Periscope-Submarine types 8B and 8C, NavShips 324-0447

Maintenance and Material Management (3-M) Manual, OpNav 43P2

BuShips Technical Manual (Chapter 9240, section II)

CHAPTER 1

ADVANCEMENT

This training course is designed to help you meet the professional (technical) qualifications for advancement to Opticalman First Class and Chief Opticalman. Chapters 2 through 12 of this training course deal with the technical subject matter of the opticalman rating. The present chapter provides introductory information that will help you in working for advancement in rating. It is strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of this training course.

REWARDS AND RESPONSIBILITIES

Advancement in rating brings both increased rewards and increased responsibilities. The time to start looking ahead and considering the rewards and the responsibilities of advancement is right now, while you are preparing for advancement to OM1 or OMC.

By this time, you are probably well aware of many of the advantages of advancement in rating—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the personal satisfaction you find in developing your skills and increasing your knowledge.

The Navy also benefits by your advancement. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can supervise, lead, and train others and thus make far reaching and long lasting contributions to the Navy.

In large measure, the extent of your contribution to the Navy depends upon your willingness and ability to accept increasing responsibilities as you advance in rating. When you assumed the duties of a OM3, you began to accept a certain amount of responsibility for the work of others. With each advancement in rating, you accept an increasing responsibility in military matters and in matters relating to the professional requirements of the Opticalman rating.

You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Repairing the periscope of a submarine is a job of vital importance, and it's a teamwork job; it requires a special kind of leadership ability that can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

Certain practical details that relate to your responsibilities for optical shop administration, supervision, and training are discussed in chapter 2 of this training course. At this point, let's consider some of the broader aspects of your increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical on-the-job language that can be understood and followed even by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are lucky enough to have highly skilled and well trained men in the optical shop, you will still find that training is necessary. For example, you will always be responsible for training lower rated men for advancement in rating. Also, some of your best workers may be transferred and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require you to be a training specialist who can conduct formal and informal training programs to qualify personnel for advancement and who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. As you advance to OM1 and then OMC, you will find that many of your plans and decisions affect a large number of people, some of whom are not in the optical shop and some of whom are not even in the same division. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Opticalman rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms in connection with the work of his own rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement in rating. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with lower rated men; sloppiness in the use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change and development. As a OM1, and even more as a OMC, you must keep yourself informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. Keep up to date on all available sources of technical information.

REQUIREMENTS FOR ADVANCEMENT

In general, to qualify for advancement you must:

1. Have a certain amount of time in grade.
2. Complete the required military and professional training courses.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NavPers 760.
4. Be recommended by your commanding officer.
5. Demonstrate your KNOWLEDGE by passing a written examination based on (a) the military requirements for advancement and (b) the professional qualifications for advancement in the Opticalman rating.

Advancement in rating is not automatic. Meeting all the requirements makes you eligible for advancement but it does not guarantee your advancement. Some of the factors that determine which persons, out of those who take the examinations, will actually be advanced in rating are the scores made on the written examination, the length of time in service, the performance marks, and the quotas for the rating.

Remember that the requirements for advancement may change from time to time. Check with your division officer or with your training officer to be sure you have the most recent requirements when you are preparing for advancement and when you are helping lower rated men to prepare for advancement.

To prepare for advancement, you need to be familiar with (1) the military requirements and the professional qualifications given in the Manual of Qualifications for Advancement in Rating, NavPers 18068; (2) the Record of Practical Factors, NavPers 760; (3) appropriate Navy Training Courses; and (4) any other material that may be required or recommended in the current edition of Training Publications for Advancement in Rating, NavPers 10052. These materials are discussed later in the section of this chapter that deals with sources of information.

THE OPTICALMAN RATING

The Opticalman rating is a general rating ONLY—there are no service ratings. Because of the nature of the work Opticalman perform, the comprehensiveness of its scope and the diversity of abilities required, an Opticalman should be a man of fairly high intelligence, good emotional stability, and high mechanical aptitude. A background of general and mechanical training is helpful.

An Opticalman is generally assigned duty in optical shops aboard repair ships or tenders. On occasions, however, he may be assigned duty ashore as an instructor in an Opticalman school. Some Opticalman receive shore duty in recruiting; others are assigned duty in Naval Reserve training, or in the U.S. Naval Examining Center, Great Lakes, Illinois, where they help to prepare servicewide examinations for advancement in rating. On occasions, Opticalmen may also be assigned duty in the Training Publications Division, Washington, D.C., to help prepare Navy Training Courses and/or other training materials, such as curricula and correspondence courses.

You should understand by now that the Opticalman rating is a VERY important rating, without which part of the mission of the Navy would not be accomplished, particularly during emergencies and under certain conditions and circumstances. Remember, then, that you ARE an important person who fills an important position on the TEAM—the United States Navy.

SCOPE OF THIS TRAINING COURSE

Before studying any book, it is a good idea to know the purpose and the scope of the book. Here are some things you should know about this training course:

1. It is designed to give you information on the professional (technical) qualifications for advancement to OM1 and OMC.
2. It must be satisfactorily completed before you can advance to OM1 or OMC, whether you are in the regular Navy or in the Naval Reserve.
3. It is NOT designed to give you information on the military requirements for advancement to PO1 or CPO. Navy Training Courses that are specially prepared to give information on the military requirements are discussed in the section of this chapter that deals with sources of information.
4. It is NOT designed to give you information that is related primarily to the qualifications for advancement to OM3 and OM2. Such information is given in Opticalman 3 & 2, NavPers 10205.
5. The professional (technical) Opticalman qualifications that were used as a guide in the preparation of this training course were those promulgated in the Manual of Qualifications for Advancement in Rating, NavPers 18068B, of June 1965. Therefore, changes in the Opticalman qualifications occurring after June 1965 may not be reflected in the information given in this training course. Since your major purpose in studying this training course is to meet the qualifications for advancement to OM1 or OMC, it is important for you to obtain and study a set of the most recent Opticalman qualifications.
6. This training course includes information that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to OM1 and OMC. However, no training course can take the place of actual on-the-job experience for developing skill in the practical factors. The training course can help you understand some of the whys and wherefores, but you must combine knowledge with practical experience before you can develop the required skills. The Record of Practical Factors, NavPers 760, should be utilized in conjunction with this training course whenever possible.

SOURCES OF INFORMATION

It is very important for you to have an extensive knowledge of the references to consult

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for detailed, authoritative, up-to-date information on all subjects related to the military requirements and to the professional qualifications of the Opticalman rating.

Some of the publications discussed here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

BUPERS PUBLICATIONS

The BuPers publications described here include some which are absolutely essential for anyone seeking advancement in rating and some which, although not essential, are extremely helpful.

THE QUALS MANUAL.—The Manual of Qualifications for Advancement in Rating, NavPers 18068B (with changes), gives the minimum requirements for advancement to each rate within each rating. The Quals Manual lists the military requirements which apply to all ratings and the professional or technical qualifications that are specific to each rating.

The Quals Manual is kept current by means of numbered changes. These changes are issued more frequently than most Navy Training Courses can be revised; therefore, the training courses cannot always reflect the latest qualifications for advancement. When preparing for advancement, you should always check the LATEST Quals Manual and the LATEST changes to be sure that you know the current requirements for advancement in your rating.

When studying the qualifications for advancement, remember these three things:

1. The quals are the MINIMUM requirements for advancement to each rate within each rating. If you study more than the required minimum, you will of course have a great advantage when you take the written examinations for advancement in rating.

2. Each qual has a designated rate level—E-4, E-5, E-6, E-7. You are responsible for meeting all quals specified for advancement to the rate level to which you are seeking advancement AND all quals specified for lower rate levels.

3. The written examinations for advancement in rating contain questions relating to the practical factors and the knowledge factors of BOTH the military requirements and the professional qualifications.

A special form known as the RECORD OF PRACTICAL FACTORS, NavPers 760, is used to record the satisfactory completion of the practical factors, both military and professional, listed in the Quals Manual. This form is available for each rating. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS columns. As an OM1 or OMC, you will often be required to check the practical factors performance of lower rated men and to report the results to your supervising officer. To facilitate record keeping, group records of practical factors are often maintained aboard ship. Entries from the group records must, of course, be transferred to each individual's Record of Practical Factors at appropriate intervals.

As changes are made periodically to the Quals Manual, new forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. Be sure that the NavPers 760 you are using includes the latest changes to the qualifications for Opticalman. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training and supervising lower rated personnel. If a man demonstrates proficiency in some skill which is not listed in the Opticalman quals but which falls within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made.

The Record of Practical Factors should be kept in each man's service record and should be forwarded with the service record to the next duty station. Each man should also keep a copy of the record for his own use.

NAVPERS 10052.—Training Publications for Advancement in Rating, NavPers 10052, is a very important publication for anyone preparing for advancement in rating. This publication lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be sure you have the most recent edition.

The required and recommended references are listed by rate level in NavPers 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Navy Training Courses that are marked with an asterisk (*) in NavPers 10052 are MANDATORY at the indicated rate levels. A mandatory training course may be completed by (1) passing the appropriate Enlisted Correspondence Course based on the mandatory training course, (2) passing locally prepared tests based on the information given in the mandatory training course, or (3) in some cases, successfully completing an appropriate Navy school.

It is important to notice that all references, whether mandatory or recommended, listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

NAVY TRAINING COURSES.—Navy Training Courses are written for the specific purpose of helping personnel prepare for advancement in rating. Some courses are general in nature and are intended for use by more than one rating; others (such as this one) are specific to the particular rating.

Navy Training Courses are revised from time to time to bring them up to date. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether a Navy Training Course is the latest edition by checking the NavPers number and the letter following the number in the most recent edition of the List of Training Manuals and Correspondence Courses, NavPers 10061 (revised).

There are three Navy Training Courses that are specifically prepared to present information on the military requirements for advancement. These courses are:

Basic Military Requirements, NavPers 10054-A.

Military Requirements for Petty Officer 3 & 2, NavPers 10056-B.

Military Requirements for Petty Officer 1 & C, NavPers 10057-B.

Each of the military requirements courses is mandatory at the indicated rate levels. In addition to giving information on the military requirements, these three books give a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities as you advance in rating.

Some of the Navy Training Courses that may be useful to you when you are preparing to meet the professional qualifications for advancement to OM1 and OMC are discussed briefly in the following paragraphs. For a complete listing of Navy Training Courses, consult the List of Training Manuals and Correspondence Courses, NavPers 10061 (revised).

Basic Handtools, NavPers 10085-A. Although this training course is not specifically required for advancement in the Opticalman rating, you will find that it contains a good deal of useful information on the care and use of all types of handtools and portable power tools commonly used in the Navy.

Blueprint Reading and Sketching, NavPers 10077-B, contains information that may be of value to you as you prepare for advancement to OM1 and OMC.

Mathematics, Vol. 1, NavPers 10069-C, and Mathematics, Vol. 2, NavPers 10071-A. These two training courses may be helpful if you need to brush up on your mathematics. Volume 1, in particular, contains basic information that is needed for using formulas and for making simple computations. The information contained in volume 2 is more advanced than you will need for most purposes, but you may occasionally find it helpful.

Opticalman 3 & 2, NavPers 10205. Satisfactory completion of this training course is now required for advancement to OM3 and OM2. Opticalman 3 & 2 and Opticalman 1 & C replace Opticalman 3, Vol. 1, NavPers 10196; Opticalman 3, Vol. 2, NavPers 10197; and Opticalman 2, 1, & C, NavPers 10198. If these courses were used to meet third class and second class advancement requirements, you should become familiar with the contents of Opticalman 3 & 2. This new course includes revised material from the previous courses and new material. Much of the information given in this edition of Opticalman 1 & C is based on the assumption that you are familiar with the contents of Opticalman 3 & 2, NavPers 10205.

CORRESPONDENCE COURSES.—Most Navy Training Courses and Officer Texts are used as the basis for correspondence courses. Completion of a mandatory training course can be accomplished by passing the correspondence course that is based on the training course. You will find it helpful to take other correspondence courses, as well as those that are based on mandatory training courses. For example, the completion of the correspondence course based on Engineering Administration NavPers 10858-C is strongly recommended for personnel preparing for advancement to OMCS. Taking a correspondence course helps you to master the information given in the training course or text and also gives you a pretty good idea of how much you have learned from studying the book.

OTHER BUPERS PUBLICATIONS.—Additional BuPers publications that you may find useful in connection with your responsibilities for leadership, supervision, and training include the Manual for Navy Instructors, NavPers 16103-C, and the Naval Training Bulletin, NavPers 14900 (published quarterly).

BUSHIPS PUBLICATIONS

A number of publications issued by the Bureau of Ships will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in BuShips publications.

The Bureau of Ships Technical Manual, NavShips 250-000, is the basic doctrine publication of the Bureau of Ships. The Manual is kept up to date by means of quarterly changes. All copies of the Manual should have all changes made in them as soon as possible after the changes are received.

Beginning with the quarterly changes dated 15 July 1963, the Bureau of Ships began to renumber individual chapters in the Bureau of Ships Technical Manual according to the Navy-Marine Corps Standard Subject Classification System. Under this system, all chapters of the Manual will eventually be part of the 9000 series which identifies ship design and ship's material subject groups. When all chapters have been renumbered to conform to the 9000 numbering system, the old chapter numbers will be eliminated. In the meantime, you will have to consult the sheets in the front of the first volume of the Manual which cross-reference the new numbering system and the old. Some of the Manual chapters remain in their old positions, so the new and the old numbers have a definite relationship to each other. For example, the old chapter 24 has been renumbered as 9240, and the old chapter 95 has been renumbered as 9950. However, some of the chapters will be moved to new locations, as well as being renumbered; in these cases, there is no clear relationship between the old numbers and the new. For example, the old chapter 6 has been moved to a new location and is now renumbered 9004.

It should be noted that chapters of the Bureau of Ships Technical Manual may be referred to by either the old chapter number or the new chapter number, depending upon which number was in use at the time of writing. If you have any trouble locating the chapter by the number given, check the cross-reference sheets given in the front of the first volume of the Bureau of Ships Technical Manual.

The manufacturer's technical manuals furnished with most equipment are valuable sources of information on maintenance, and repair. The manufacturers' technical manuals for periscopes and other optical equipment are usually given NavShips numbers.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. A selected list of training films that may be useful to you is given in appendix I of this training course. Other films that may be of interest are listed in the United States Navy Film Catalog, NavWeps 10-1-777. This catalog, published in 1966, supersedes three earlier publications: the former catalog with the same title but numbered NavPers 10000-A; the Supplement, NavWeps 10-1-772; and the Navy Classified Film Catalog, NavPers 10001-A.

When selecting a film, note its date of issue listed in the film catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may still have sections that are useful, but it is important to note procedures that have changed. If there is any doubt, verify current procedures by looking them up in an applicable source.

CHAPTER 2

SHOP SUPERVISION

As an OM1 or OMC, one of your major responsibilities will be to supervise the repair and overhaul of optical instruments. In order to supervise optical shop work most efficiently, you will rely mostly on your past experience in shop work and repair procedures. In addition to this, you will be required to maintain certain records and reports, conduct and supervise an effective training program, and give accurate estimates as to the time required to complete repair work.

It is impossible to cover all the procedures and problems that arise in the work of a shop supervisor. By studying this section, you will become aware of some of the things that occur, particularly in regard to the job of setting up shop procedures, and the methods by which everyday problems are solved in an optical shop.

RECORDS AND REPORTS

As you advance in rating to OM1 or OMC, you will be required to assume more responsibility for the paperwork which is so necessary in a well organized shop. In fact, to avoid bogging down completely in the mass of details, you will probably delegate some of these duties to an assistant in the shop. Keeping all your records up to date will enable you to keep a close check on each job, each workman, and each piece of equipment under your supervision. The ship will have standard forms for keeping some of the required records; for example, work request forms, supplementary job order forms, and the necessary requisitions for obtaining repair parts and supplies. You may supplement these forms with shop logs and notebooks of your own design to meet your specific needs.

A WORK PROGRESS LOG is a record of all the current and completed work accomplished by your shop and by each man assigned to your shop. This log may be one of your own design, but it should contain the following pertinent data: Job order and work request number, date received, name of the activity requesting the work, brief description of the job, name of the man assigned to do the job, and the number of man-hours expended.

A MATERIAL EXPENDED RECORD is a running inventory of your stockpile including such information as the date material was received, the jobs on which the material was expended, and the balance on hand. To facilitate the preparation of stub requisitions, such data as quantities listed on the shipboard allowance list, location of the spaces where the materials are stored, and stock numbers may be included. This record is particularly valuable on repeat jobs such as the repair of small instruments.

An EQUIPMENT LOG is a list of the various tools charged to you and their location—whether in the shop or storeroom, or assigned to an individual; the location of repair parts boxes can also be logged in this notebook. An equipment log kept up to date with adequate tool descriptions--make, model, and serial number—will be of great assistance to you in making periodic inventories.

A MAN-HOUR REPORT is submitted daily to the head of the department through the division officer. A summary of both productive and nonproductive work may be included in this report. Nonproductive work includes training, shop upkeep, general drills, and special details such as field day, mess cook, compartment cleaner, and master-at-arms assignments. This form, when submitted by all of the shops in the department, gives the repair officer a complete picture of the working day.

For further information on Navy records and reports refer to BuShips Technical Manual, chapter 9004 (6).

CARE OF TOOLS AND EQUIPMENT

Orderliness is a prime essential of good shop operation. There must be a place for every tool and each tool must be returned to its place after use. By seeing that this practice is observed, the men under your supervision will be able to find any tool at any time, without wasted effort.

In an optical shop, cleanliness, like orderliness, is a very important factor. If tools are to serve their purpose most satisfactorily, they should be wiped with a cloth containing light oil after they have been used. Tools aboard ships and in other localities of high humidity should be wiped at least once a week (whether or not they have been used). In applying oil, care must be taken to see that it does not get on the wooden handles of screwdrivers and other tools.

An untidy shop is an unsafe shop. For this reason it is important that tools, machinery, workbenches, and floorspaces be kept clean. Greasy and oily rags in piles are fire hazards. Spilled oil on benches and decks may cause serious injury. All equipment should be checked to make sure that guards have been installed and that they are kept on all moving parts of equipment.

Operating instructions and safety precautions should be posted at each machine. It is good engineering practice to comply with all the requirements listed in the operating instructions and safety precautions.

SHOP HOUSEKEEPING

Generally, you can give a workshop one good look and tell whether it is efficient and well run. Just make a quick survey for cleanliness, neat tool and stock stowage, and the condition of equipment. If such a survey reveals a high quality of housekeeping, it can also be assumed that the shop is well organized and really turns out the work.

Material and supplies—screws, bolts, and gasket material—must be stored in a convenient, secure, and orderly place. Use cabinets, shelves, bins, and racks arranged in the shop to give the greatest possible amount of free working space.

If shop space permits and sufficient tools are available, each man should have his own stowage drawer and toolbox in which he can keep the tools that are ordinarily used. (No man likes to use a drill bit that someone else has nicked or burnt, and each one likes to have his own hammer, chisels, and screwdrivers.) Besides speeding up production of work, this method of stowage will provide better care and cleanliness of handtools.

If space permits, one corner of the shop may be blocked off for use as a TOOLROOM. In this room can be kept such tools as portable power drills, grinders, grinding wheels, large dividers, pipe wrenches, C-clamps, large drill bits, special files, dies, tap wrenches, and diestocks. A striker should be made responsible for keeping the tools in order and issuing them as required. This toolroom job should be rotated among the strikers to give each man an opportunity to learn the names and uses of all the tools.

Tool stowage is an important item in the optical shop. Lockers, racks, drawers, cabinets, and boxes are used for stowing tools. The place selected depends largely on the USE of the tool, the frequency of its use, its size and shape, and its value.

Drill bits, micrometers, torch tips, combination squares, gages, and the like must be stowed so that they are protected from contact with other tools. Edged tools and pointed tools, such as scribers, dividers, and compasses, require special stowage to prevent damage to cutting edges and sharpened points.

Particularly valuable and hard-to-get tools should be kept locked in special lockers, drawers, cabinets, or toolboxes. These include portable power tools, gages, micrometers, special pliers, wrenches, files, and drills.

Tools frequently used outside the shop should be made up in kits and stowed in convenient toolboxes. Tools used in your shop may be marked with a distinctive color for identification. If so marked, they are not easily mixed with tools that belong to other shops.

Good housekeeping requires that bench tops and power equipment be kept clear of unnecessary tools and material, scrap stock, filings, dirt, and excess oil and grease.

INVENTORY OF TOOLS AND EQUIPMENT

One of the jobs of the supervisor of an optical shop is to maintain a system of accountability for valuable tools and equipment. He should see that custody cards are made out for tools and equipment requiring custody signatures. These include such items as portable power tools, gages, micrometers, and special sets of handtools. Tools which are of a highly pilferable nature should be accounted for by inventory at regular intervals. All accountable tools issued from the toolroom should be returned at the end of the working day, unless special permission has been obtained to keep them out for a longer period of time.

In making a complete inventory of tools and equipment, the Coordinated Shipboard Allowance List (COSAL) is used. The COSAL is the official source which contains the allowance of machinery, equipment, accessories, tools, and repair parts furnished the optical shop. A detailed description of the COSAL is given in Military Requirements for Petty Officer 3 & 2, NavPers 10056-B.

SAFETY PRECAUTIONS

You should ensure that the following precautions for the safety of personnel are known and observed by the operators of all types of power-driven tools:

1. Do not attempt to operate a machine with which you are not familiar.
2. Before operating a machine, see that there is plenty of light to work by.
3. Do not operate electrically driven machines, either stationary or portable, without observing the proper electrical safety precautions.
4. Shut off the power supply to any machine that is being repaired or adjusted; and attach the prescribed warning card to the switch, to ensure that the machine will not be energized by other personnel.
5. Do not allow machines to run unattended.
6. Never lean against a machine that is running.
7. Keep machine guards in position at all times unless removal is authorized by the shop supervisor.
8. Replace machine guards after repairs or inspections have been completed and before the machine is started.
9. Do not distract the attention of a machine operator.
10. Do not wear loose or torn clothing, gloves, neckties, long sleeves, or rings while operating a machine.
11. If clothing becomes caught in a machine, shut off the power immediately.
12. When using portable electric equipment around machine tools, take special care that electrical cords are clear of moving parts.
13. Clamp workpieces securely to the machine, particularly on drill press operations. (Use vises or other adequate holding devices when working on small parts.)
14. Do not exceed the recommended depth of cut, cutting speeds, and feeds.
15. Keep the areas around machines clear of obstructions and in a nonslippery condition.
16. Remove chips with a brush or other suitable tool—never by hand or with compressed air.
17. Always wear goggles or a face shield when grinding, or when there is danger of flying chips.
18. Do not operate electrically driven portable handtools wihout a ground connection between the metal housing of the tool and the steel structure of the ship. When possible, use only tools equipped with a properly grounded plug, see that the grounded plug is inserted in a grounded receptacle. If the tool is equipped with a 2-contact plug and a supplementary ground wire, see that the ground wire is securely attached to the ship's structure by a clean metal contact. Where the ground wire is independent of the tool plug, the wire should always be connected BEFORE the plug is inserted in the receptacle and should not be disconnected until AFTER the plug is pulled out. Where portable tools are provided with grounded plugs, this sequence of connecting the ground first and disconnecting it last is automatically provided for in the arrangement of the contacts in the grounded plug and grounded receptacle. It is, therefore, in the interest of safety and convenience to install these grounded plugs on all portable tools.

PLANNING THE WORK

The optical shop supervisor, with the assistance of his leading petty officers, must plan each phase of each job that is assigned to his shop. The planning of the day's work must include the lead jobs, the assist (supplementary) jobs from other repair shops, the routine upkeep and maintenance, and nonproductive work such as working parties. Lack of good planning will usually result in confusion, delay, and sometimes failure to meet the commitments of the shop. The supervisor must plan for the coordinating of the various steps in the work. This involves consideration of available manpower, equipment, materials and the workload of the other repair shops.

Planning does not stop in the shop. The repair officer must know how many productive man-hours are to be available for repair work, during a specific availability, to enable him to know how much work can be accepted during that period of time. This is where estimating comes into the picture. The shop supervisor must have the ability to give an accurate estimate of the time that each of the jobs assigned to his shop will consume. To do this, he will rely heavily on his past experience and the experience of his leading petty officers. He must also estimate the nonproductive man-hours that will be required to meet his shop's obligations to provide for working parties, mess cooks, special liberty, etc.

In planning the work, the capabilities of the men must be considered. Assigning an inexperienced man to a difficult job requires that an experienced man be on hand to give direct supervision at all times. If the work load of the shop is light, this is a good training opportunity. However, if the shop has a heavy workload the inexperienced man would be of more value assigned to a job requiring skills more in line with his experience.

Another question to be answered is the number of men required to accomplish the job. Too many men working on the same piece of equipment is sometimes worse than not enough. Each job will have to be analyzed step by step and then the required number of men assigned.

Still another factor that must be considered is the necessary materials to accomplish the needed repairs. What kind of materials, how much is needed, where is it obtainable, and how much time will be taken to obtain it, are all questions that must be given much consideration. Possibly the material called for in the blueprint is no longer available. The research required in finding a suitable substitute takes time. These factors all must be considered by the supervisor of the optical shop.

There are some materials that can be kept in the optical shop in sufficient quantities to avoid delay caused by frequent trips to the issue room. For some items a 30-day supply is adequate, for others, a 90-day supply may be necessary.

Usually, the OM1 or OMC will know from experience where each item is in the shop; he keeps his locator file in his head. He should also attach a list of the contents to each drawer or cabinet so that the rest of the men in the shop will also know where things are stowed. Remember the importance of good housekeeping in getting the work out. Have a place for everything and keep everything in its place. It is also important that your storage facilities have adequate provision for securing for sea.

Estimating the amount of material required to complete a job is your responsibility. Unless you are able to estimate with accuracy the amount and kind of materials required by your shop, you will either be caught short without the items you need or you will find your shop cluttered with items you do not need. A high inventory level of slow moving materials ties up division funds that might be used to better advantage. Remember that running a shop is like running a business; you must operate within a budget. Much of the guesswork in estimating can be eliminated if you make proper use of records of material expended during the previous quarter. Include the amount of material required for any special work which you know is to be done during the period for which you are estimating. Plan and place shop orders for materials in advance with the supply officer through the division officer or department head. Do not bypass any of the normal supply channels of authority.

Inventory levels for most consumable items and repair parts are maintained by the supply department. Aboard some repair ships or tenders, the OM1 or OMC will assist the supply officer in maintaining the inventory on optical parts. Usually a high limit will be kept on hand. Before the low limit is reached, the OM1 or OMC will request that material be obtained to replenish the stock and maintain the high limit supply. In ordering, take into consideration the rate of use, the balance on hand, and the expected delay in shipment and delivery. Information concerning the procurement, custody, and inventory of repair parts and other supplies is covered in Military Requirements for Petty Officer 1 & C, NavPers 10057-A, and in Military Requirements for Petty Officer 3 & 2, NavPers 10056-B.

In planning a job, the CPO or PO1 in charge of the shop must first perform the job step by step mentally. This procedure will help prevent the unintentional omission of some important step of the job. Once the steps are outlined, consideration should be given to each step to make sure that all requirements are taken into account.

After the job has been analyzed, the sequence of the operations must be determined. In some jobs the more time consuming operations may be performed first so that the largest part of the job is completed first. In other jobs, the less time consuming operations may have to be done before any other operation can be performed.

Once the planning of the work has been done, follow the plans carefully. However, it is also necessary to be flexible, in order to meet any unforeseen circumstances or make emergency repairs. If a change in plans is indicated, the supervisor must reevaluate the whole plan and make such changes as he believes necessary. Careful planning and the followup of these plans will enable you to run your shop with the utmost of efficiency and productivity.

LAYING-OUT AND ASSIGNING WORK

A Navy optical shop is primarily concerned with repair work. The assignment of work changes constantly according to the amount and type of work being done in the shop. When the workload is light, the less experienced men may be assigned to a complicated job under the supervision of an experienced petty officer. When the workload is heavy the most experienced men will have to be assigned to the complicated jobs and to those jobs that are of an urgent nature. At times reassignment of work must be made to prevent delays, to accomplish added new work, or to expedite emergency jobs.

INFORMATION ON INCOMING JOBS

Job orders generally will be received in the shop several days in advance of the work. The shop supervisor should start his planning as soon as possible to gain an advantage of time. Much of the planning may be done before the work is delivered to the shop. Jobs that have been done before may be planned in such a manner that the necessary repair parts are on hand or the blueprints are obtained from the technical library. Usually the activity requesting the repairs will provide the plans or blueprints along with the job order.

Another source of information is the manufacturers' technical manuals. Many of these may be found in your own technical library or may be obtained from the activity requesting the repair work. From these sources of information much advance planning can be done prior to the delivery of the equipment to be repaired.

PRIORITY OF JOBS

In planning and scheduling work in the shop you will have to give careful consideration to the priority of each job order. Priorities are generally classified as urgent, routine, or deferred.

Deferred jobs do not present much of a problem, as they are usually accomplished when the workload of the shop is light and there are few jobs of a higher priority to be done. Also, when these jobs are approved it is with the understanding that they will be accomplished when the time, personnel, and equipment are available.

The majority of job orders will have the routine priority assigned to them. Routine jobs make up the normal workload of the shop, and must be carefully planned and scheduled so that the daily organization and production can be maintained at a high standard.

The urgent priority jobs require immediate planning and scheduling. Other jobs, of lower priority, may have to be set aside so that these urgent jobs can be accomplished. At times it may be necessary to assign men to a night shift so that these jobs can be completed on time.

DETERMINATION OF REQUIRED REPAIRS

When a job is delivered to the shop, one of the first things to be done is to determine what kind of repairs are required. This is where the years of practical experience and up-to-date knowledge on different types of repair procedures are invaluable. During the planning stage, check with some of the leading petty officers in the shop for ideas on how best to accomplish the necessary repairs. Perhaps one of them may have done the same job before. It may be possible to assign some of the planning work to them; for example, a job of overhauling a rangefinder may be given to a man in the shop who has demonstrated his ability to do this type work.

After the necessary repairs have been determined, the shop supervisor must ascertain that the repair parts or materials are available. If they are not available on board, they must be requisitioned through the supply department. The activity requesting the repairs may even have the necessary repair parts on hand. If so, they may be used by the repair activity and then replaced when available. Frequently, the repair parts must be manufactured or possibly temporary repairs made to the old parts. Matters

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of this nature must be cleared up before the job is laid out and assigned to less experienced personnel in the shop.

SCHEDULING OF WORK

The main object in planned scheduling of work is to have the work flow smoothly and to have the next job ready without delay, since lost time between jobs lowers the overall efficiency of the shop. Because of the variety of jobs which you and your men will be required to perform, specific work schedules must be prepared to make sure that all work is completed. These work schedules must be flexible enough to adapt to changes in priorities, transfer of personnel, temporary breakdowns of equipment, unscheduled ship drills, or any other emergency that may come up from time to time.

The priority of job orders, as well as the length of time required to complete them, will determine the scheduling of work. Jobs of urgent priority will be accomplished first before routine jobs are started. The deferred jobs or the jobs of least importance are left until last; then they can be done or canceled, depending upon the workload of the shop.

It may be necessary to change the schedule of work in the shop when new high-priority jobs come in. Sometimes other work must be temporarily set aside until these urgent jobs are completed. Experience, judgment, and foresight are required to maintain an organized scheduling of work in a large optical shop, in order to get the numerous jobs finished at their respective times.

ESTIMATING TIME FOR A JOB

Estimating time for the completion of a job requires considerable thought and foresight. Upon your estimate may depend the success or failure of a ship to meet its operational commitments. Failure to complete a job in the allotted time can result in considerable unnecessary expense and loss of valuable time. Each estimate that you make must be realistic, accurate, and dependable. An estimate, in a very real sense, is a guess, but it should be an intelligent guess based on the proper use of records and experience.

For most of the routine jobs that come into the shop, the shop supervisor may give a quick estimate of the probable time of completion. Generally, there is no necessity for completing routine jobs within any set time as long as the repairs are completed before the end of the availability, and in sufficient time for the ship's force to install the repaired equipment.

The estimation of time required to complete jobs of an urgent nature (priority) must be given considerable thought. If a last minute job comes up near the end of the repair period, or if a ship in port for only a day or two requires an urgent repair job, the time required to make the repairs is an important consideration. In jobs such as this, the time estimate must be extremely accurate to avoid the waste which would result from starting a repair job that could not be completed. Frequently, the final decision will be made by the OM1 or OMC in charge of the optical shop; because of his experience in repair work, his knowledge of the current workload, and his knowledge of the men and machines in the shop, he should be able to give an accurate estimate of the time required to complete almost any repair job.

Before any estimate can be made, detailed information on the job must be on hand. Where necessary, blueprints and manufacturer's technical manuals should be studied. A thorough study of the item requiring repairs must be made because the job might require repairs or replacements in addition to those originally specified. A decision has to be made as to the amount of repair work that is to be done. Detailed procedures on how best to accomplish these repairs must be clearly understood. In other words, one should know all the details of the repair job, before starting to consider the length of time required to do the job.

When the necessary repairs have been determined, consideration may be given to a time estimate. The optical shop supervisor must consider the various phases of the repair operation when calculating the time it should take to perform a given operation on any part and on any specific instrument.

TEARDOWN TIME

In any repair job, the instrument to be repaired is disassembled only as much as is necessary to enable the repairs to be made without damage to other parts of the equipment. The teardown time is that time required to disassemble a piece of equipment after it has been delivered to the shop. The teardown time is then doubled to allow sufficient time for reassembly. If it is necessary to do any

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dismantling before delivery to the shop, an estimate of this time will be made by the ship's force (customer ship) or by other repair department personnel.

MISCELLANEOUS TIME ALLOWANCE

The final factor to consider in estimating time is often overlooked. This is the time that falls into the category of miscellaneous. Some of the miscellaneous factors are: fatigue from mind and muscle exercise, personal time allowances such as head calls, rest breaks, or meals, and such other items that would not fall into any of the other categories given here.

The time factors that have thus far been considered are those that have to do with the overhauling of a piece of equipment or making repair parts. There are certain other factors that must be considered in order to make a realistic and accurate time estimate. Some of these are: the shop workload of other repair shops and any time consuming errors.

SHOP WORKLOAD

The workload of the shop must be carefully considered before a new job is approved for completion within a certain time.

After a decision has been made as to what repairs or replacements are necessary, the petty officer in charge will be able to determine what tools and personnel should be used for the job. The next step is to check on the present and scheduled work. If an urgent priority has been given to the new job under consideration, then the work being done by the repairman will be set aside until the proposed job has been completed. If the new job does not have an urgent priority, it must be dovetailed, in accordance with its priority, into the schedule of work being done.

Another decision must be made concerning the personnel to be assigned to the new job. This new job may require experienced personnel who may have to be taken off other jobs. If the new job is a complicated one, a leading petty officer may have to be assigned to process the job through the shop, including disassembling, inspections, assembling, and tests. The number of required personnel, as well as their technical ability, must be considered. (Sometimes, a job can be completed in less time by assigning more men to do the work. However, there are limitations as to the number of men you can put on a given job. Don't assign unneeded men.)

Another item that must be decided is the number of hours per day that will be assigned for personnel to work on the new job. If it is to be a routine job, normal working hours will be considered. If it is a rush job with an urgent priority, three shifts will be assigned to the job and men will be working 24 hours a day on it.

In brief, the selection and assignment of personnel will depend upon the magnitude and complexity of the new job under consideration as well as its assigned priority. This in turn depends upon the workload of the shop, except where the new job is given an urgent priority.

REQUIRED PARTS AND MATERIAL

After a decision has been made as to the extent and nature of repairs that are required, a check must be made to see if the required material and parts are on board ship. The material must be available before an attempt is made at estimating the time of a repair job. Such items as gaskets, studs, bearings, and shaft keys that may be required must not be overlooked.

Naval ships carry an allowance of repair parts for machinery and equipment on board ship. A check of the ship's COSAL will show if a certain part is supposed to be carried on board. There have been instances where this check has been overlooked. There is certainly no need to manufacture an item such as a gear if the ship carries gears for the instrument that requires repair. Locating available repair parts will save a great deal of time in doing the repair job, and one's estimate can be made accordingly.

CONSIDERATION OF THINGS THAT MAY GO WRONG

Experience is an excellent teacher of things that may go wrong when doing a repair job. An experienced supervisor can avoid many of the difficulties that may arise in performing repair work. When planning and estimating a repair job, the possible difficulties that may arise should be carefully considered, and extra time allowed for them. Adequate blueprints or other drawings should be on hand. If you have sufficient information before starting the job, and a clear view as to the total amount of repair work that will be required, it is easier to avoid mistakes and delays.

The repair job itself may cause a certain amount of breakage or damage; and the supervisor who has estimated 30 minutes for removal of the parts may find that the whole job actually takes 4 hours.

Failure to ensure that a man fully understands the details of the work may result in spoiled work. While the supervisor may have all the details on the job, this is not sufficient if the man doing the job ruins it because of lack of information or a misunderstanding as to what should have been done. The supervisor must make sure that the detailed instructions are thoroughly understood by the men doing the actual work. Some relatively inexperienced men fear to appear ignorant and want to make a good showing by saying that they understand the instructions, without fully appreciating what is meant. When the job, or part of it, has to be done over, the original estimated time of completion will no longer hold true.

When the unit that is to be repaired consists of a number of assembled parts, there may be difficulties in removing the various parts. Parts may be rusted or forzen so that it is extremely difficult to remove them. On the original inspection of the items in need of repairs, the supervisor should watch for any indication that the unit may be difficult to disassemble. Then he should make an extra allowance of time in his estimate to cover this phase of the repair job.

If an item fails to pass any required tests after repair, additional work will be necessary. The required tests, and the possibility of additional work associated with tests, must be considered when making an estimate of time required for the repair job.

The time required to deliver the instrument to the shop should not be included on estimated time to do a repair job in the shop. When boat and crane service are involved in a proposed job, this fact should be brought up for consideration by the person or activity requesting an estimate of the time required by the optical shop. When requested to estimate this time of transportation, the supervisor of an optical shop should make an estimate, distinct and separate from that for the work of his own shop. Boat and crane service may be unpredictable at times, and the supervisor should check with the officer of the deck and the crane operator before making an estimate of this kind.

When planning on the required personnel for the job, a check should be made for the possible inspections, drills, and working parties that may occur which will delay the repair job. If the assigned men cannot be excused from these activities, extra time must be added for the completion of the repair job.

The factors discussed do not make a complete list of things that may go wrong on a repair job, but they indicate the type of things which will have to be considered when estimating the time required to do a repair job.

SUPERVISING REPAIR WORK

One of the most important duties of a First Class or Chief Opticalman is that of supervising the repair work in the optical shop. The supervisor must instruct shop personnel concerning the different repair jobs which have to be done; he must check on the progress of the work, and give additional advice or instructions when necessary; and he should check the completed job to see that it has been done properly and in accordance with his instructions.

After the supervisor of the optical shop has obtained complete information on a new job and has decided what repairs or replacements are necessary, he must then decide who is to do the job. In order to make this decision, the supervisor must know what experience the men have had with different types of repair work, and what skills they have in operating the various machine tools.

The shop supervisor should see that all items coming into the shop are properly tagged. The men in the shop should be instructed to replace any tags which have been removed in order to overhaul an instrument. The mixup of some items, can cause, at the very least, a lot of unnecessary confusion and lost time.

STARTING THE JOB

The man who is going to do the repair job must be given detailed information on how the job is to be done. The shop supervisor should be careful to see that the man fully understands what he is going to do, so as to prevent any mistakes due to misunderstanding of instructions. The amount of instruction depends upon the knowledge and experience of the man concerned. If he is an experienced man, it may be only necessary to give him a blueprint and tell him what parts have to be made or what repairs are to be accomplished. There will be times when a blueprint will not be available. The supervisor will then have to make a sketch of the part or parts to be manufactured. This sketch will make the job easier and more understandable for the man doing the work. A thorough understanding of Blueprint Reading and Sketching, NavPers 10077-B, will be of great help to the shop supervisor in performing this task.

Inexperienced men will need additional instructions for setting up the work in the machine, and information on the proper procedure in doing the job. Men in the shop should understand that they are free to ask questions if they are in doubt about any details in doing their assigned work. Men will ask questions when they see that it is to their advantage to do so.

In addition to giving instructions on how a job is to be done, it is also advisable to give the men some information concerning the importance of the job, the origin of the job, the part that each person will play in accomplishing the complete repair job, and the reasons for certain specifications. In general, men are interested in why a job is done, and how it is done, and will usually turn out better work if they have a clear picture of the whole job.

CHECKING THE PROGRESS OF WORK

The assignment of a job is only the first step in processing a job through the shop. The supervisor of an optical shop must know his men. He should have a fairly good idea of each man's skill, ability, and knowledge for accomplishing the repair work.

The best way in which the shop supervisor can obtain this knowledge is to inspect the shop frequently and check the progress of the various jobs in the shop. In that way, the supervisor will have a good idea as to which jobs, or which men, will require the most checking or inspecting.

When checking on the progress of work, the supervisor should be sure that the men are observing proper safety precautions in regard to themselves and the machines that they are operating.

In case of any doubt, the supervisor should check that the men understand his instructions properly or are doing the work correctly as indicated by the blueprint or drawing. If necessary, the supervisor should provide additional instructions to give a better understanding of the job, or to improve workmanship. By frequently talking to the men and answering their questions, the supervisor can prevent jobs from being spoiled, as might happen if he were not available to give the correct details on the jobs. The supervisor who has interest and confidence in his men and their work will find that men have confidence in him as a good shop supervisor.

Complications may develop on some repair job, which may require additional planning and revised repair procedures. By observing the progress of the various jobs, and whether any are ahead or behind the planned schedule, the supervisor will be able to change the schedule of some jobs in order to prevent "bottlenecks" and to keep the most important jobs moving.

CHECKING ON COMPLETED JOBS

When a job has been completed in the shop, the supervisor should inspect and approve the job. Inspection is necessary to ensure that the repair job or the manufactured replacement parts will be satisfactory both to the repair activity and to the ship's force that is going to use and depend upon the equipment that has been repaired. Inspection of parts may be accomplished either visually or by means of measuring instruments. In addition, when applicable, shop tests are performed to check the condition of repaired equipment.

The completed job order should show the man-hours, the material used, and a full description of the work accomplished. In addition, the necessary shop records and paperwork should be correct and up to date. When the job has been completed, the interested parties should be notified as soon as practicable; completed jobs should not be left to accumulate in the shop, as some of the items may become mixed up, damaged, or lost.

Before releasing a completed item, the shop supervisor should check to be certain that: (1) The correct job order is signed by a representative of the requesting activity, (2) the identification on the item and on the job order coincide, and (3) all manufacturers' technical manuals and blueprint furnished with the job order are returned.

TRAINING SHOP PERSONNEL

The first impression formed by a new man in the shop will be a lasting one. If the petty officer in charge of an optical shop has a well-planned program for introducing new men to the work in the shop, he has taken a most constructive step toward building high morale. One of the best stimulants for the development of high morale among new men is to have them realize that their boss appreciates their feeling of strangeness and is aware of their desire to make good. There is often a gap between the point at which a man is assigned and the time that he has developed into a satisfied worker. Proper introduction to the work, a well-planned training program, and counseling when necessary will turn the ill-at-ease man into a confident and interested worker.

The shop supervisor will find it a profitable procedure to review with each new man such matters as the mission of the ship and how the shop fits into the overall picture; the policy on drills, liberty and leave; and the man's duties and what is expected of him as an individual. The supervisor should be sincerely interested not only with getting acquainted with the man but in being sympathetic with the problems that may arise in getting settled. The initial contact should be primarily to win the man's confidence. The supervisor may later turn the man over to a qualified petty officer who is capable of completing the introduction process and the early training that is necessary. Usually, considerable information can be given to the new man by an experienced petty officer selected by the supervisor to complete the introduction period.

In carrying out his responsibility for introducing the new worker to the job, the supervisor must do a certain amount of planning if the instructions necessary for the proper indoctrination of the new worker are to be carried out effectively.

At this point, it may be well to indicate one fundamental difference between the work of a supervisor and that of his men. The men work with machines and materials, while the supervisor works through people to produce the desired results with the machines and materials. The machines may be operating perfectly and the materials may be of the best quality, but unless the men who handle them are properly instructed, adjusted to their work, and cognizant of their place in the organization and of the policies of the department, they will not be satisfied workers. The supervisor is responsible for developing high morale in his shop.

The first step in this process is attained by properly indoctrinating each new man at the time of his entrance into the work area. There are three general areas of indoctrination.

1. Those dealing with facts, such as the shipboard rules and regulations.

2. Those dealing with the men's attitudes or feelings, their confidence in the organization, pride in the job, and respect for their fellow workers.

3. Those dealing with skills, safe working habits, and quality of work.

To aid in developing men for greater responsibilities is everyone's job. Each person not only must be receptive to that which helps to develop himself, but must also help to develop those who assist him in his work. However, the petty officer in charge of a machine shop has the direct responsibility of seeing that all his subordinate petty officers understand their work and its relation to the function of the optical shop so well that they automatically teach those who assist them.

SUPPLIES

This book is intended as a training guide for the technical requirements of your rating, so information related to supply is not included. However, it is important that you know something about supply problems in your rating. The Military Requirements for Petty Officer 3 & 2, NavPers 10056-B, and Military Requirements for Petty Officer 1 & C, NavPers 10057-A, will give you most of the information you will need for working with supplies in the optical shop.

MAINTENANCE AND MATERIAL MANAGEMENT

Shipboard maintenance programs in the past have varied from one command to another, resulting in various degrees of operational readiness. A relatively new, uniform system of scheduling, recording, reporting, and managing ship maintenance is now in use. This system is called the Standard Navy Maintenance and Material Management (3-M) System and is designed to upgrade the operational readiness of ships.

The 3-M System is not to be considered a "cure-all" for all equipment and maintenance problems. The system does, however, provide a logical, efficient approach to these problems by launching a forthright attack on electrical, mechanical, and electronic disorders. The system also produces a large reservoir of knowledge about equipment disorders, which, when fed back to the appropriate sources, should result in corrective steps to prevent recurrences.

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The 3-M System consists primarily of a Planned Maintenance System (PMS) which provides a uniform system of planned, preventive maintenance; and a Maintenance Data Collection System (MDCS) to provide a means of collecting necessary maintenance and supply data, suitable for rapid machine processing. A Manhour Accounting System, also called Exception Time Accounting (ETA), is installed in the repair department of repair type ships in conjunction with the MDCS.

The 3-M System, like any other system or program, is only as good as the personnel who make it work. Your role in the system as a PO1 or CPO will include the training of lower rated personnel in its use, as well as the scheduling and supervision of maintenance. General information concerning all aspects of the system is included in this chapter but as a leading petty officer, you should keep abreast of new developments and changes to the system. Details on the system and changes related to it are available in the Maintenance and Material Management (3-M) Manual, OPNAV 43P2 (revised). Other sources of information include OPNAV Instruction 4700.16 (revised), the Bureau of Ships Journal, and directives issued by type commanders.

(NOTE: The principles and procedures involved in the Standard Navy Maintenance and Material Management (3-M) System are the same for all ratings. Planned maintenance requirements have not been determined for that equipment which the Opticalman maintains; therefore the examples used in this chapter are applicable to ratings other than Opticalman.)

PLANNED MAINTENANCE SYSTEM OPERATION

The planning and scheduling of planned maintenance is accomplished through the Planned Maintenance System (PMS). In addition, the PMS defines the minimum maintenance required, controls its performance, describes the methods and tools to be used, and aids in the prevention and detection of impending casualties. These factors should prove to be a definite asset to the leading petty officer in forecasting future material requirements and in the proper utilization of available manpower.

In establishing the minimum planned maintenance requirements for each piece of equipment, the Bureau of Ships Technical Manual, manufacturers' technical manuals, and applicable drawings are critically examined. If the maintenance requirements are found to be unrealistic or unclear, they are modified or revised before being incorporated into the PMS.

It is possible that the planned maintenance prescribed in the PMS may conflict with that prescribed in other documents such as the Bureau of Ships Technical Manual. Should this happen, the PMS supersedes and takes precedence over any and all documentation that may be in conflict with it. All tests, inspections, and planned maintenance actions should ultimately be incorporated in the PMS.

The Planned Maintenance System is based upon the proper utilization of Planned Maintenance System Manuals, Maintenance Requirement Cards (MRCs), and schedules for the accomplishment of planned maintenance actions.

The Planned Maintenance System Manual

The Planned Maintenance System Manual contains the minimum planned maintenance requirements for each component installed for a particular shipboard department. A separate Planned Maintenance System Manual is furnished for each department. The manuals are individually compiled for each ship, thereby assuring a tailored system.

The Planned Maintenance System Manual is normally kept in the departmental office and is used by the department head, division officers, and leading petty officers in planning and scheduling maintenance. The manual contains a list of effective pages and a section for each division or maintenance group within the department. Information to be found on the list of effective pages includes the components installed, the APL/CID number, the manufacturer of the component, and the NAVSHIPS number for the appropriate manufacturer's technical manual. Each divisional section contains index pages for each system, subsystem, or component which requires a planned maintenance action. These pages are referred to as Maintenance Index Pages (MIPs). Each Maintenance Index Page contains a brief description of the maintenance requirements and the frequency with which the maintenance is to be effected. The frequency code is:

D-Daily
W-Weekly
M-Monthly
Q-Quarterly

S-Semiannually
A-Annually
C-Once each overhaul cycle
R-Situation requirement (e.g. 100 hours of operation)

In addition, an index page includes the rate(s) recommended to perform the task and the average time required. A sample Maintenance Index Page (OPNAV Form 4700-3) is shown in figure 2-1.

The manpower available will vary from one ship to another; therefore the information found on the MIPs regarding rates recommended to perform a maintenance task and the average time required for the task requires certain clarification. The maintenance tasks are actually performed by personnel available and capable, regardless of what rating is listed on the MIP. The average time required, as listed on the MIP, does not take into account the time required to assemble the tools and materials to do the maintenance action nor the time required to clean the area and put away the tools at the end of the task.

That portion of the Planned Maintenance System Manual which contains the Maintenance Index Pages applicable to the equipment under a specific division or maintenance group is called the Group Maintenance Manual. A copy of the Group Maintenance Manual, in addition to the one in the departmental Planned Maintenance System Manual, is kept in each working space as a ready reference to maintenance personnel.

The Maintenance Requirement Card

The Maintenance Requirement Card (fig. 2-2) defines a planned maintenance task in sufficient detail so that assigned personnel can perform the task with little difficulty. Each Maintenance Requirement Card lists the rate of personnel recommended to perform that particular task; the safety precautions that must be observed; the time, tools, parts, and materials required for the task; and the detailed procedures for performing the task. A complete set of applicable Maintenance Requirement Cards is maintained in each working space with the Group Maintenance Manual. A master set of all Maintenance Requirement Cards is kept on file in the departmental office. If a card is lost, or if it becomes torn or soiled, it can be replaced by typing a duplicate card from the master set or by ordering one through the proper channels.

The Maintenance Requirement Card is one of the primary tools of the PMS system to be used by the personnel actually performing maintenance tasks. Personnel assigned to maintenance tasks will remove pertinent cards from the set which is maintained in the working space; obtain the stated tools, parts, and material; perform the maintenance requirement as specified on the card; correct and report any deficiencies noted during the performance of the maintenance requirement; and return the card to its proper place after the task has been completed.

Maintenance Requirement Cards represent the minimum planned maintenance requirements of the cognizant material bureau. The command has the prerogative to increase minimum requirements to meet local conditions. If these changes are of a continuing nature, recommended changes in the system should be submitted to the bureau.

Scheduling of Planned Maintenance

Through the use of a cycle schedule (fig. 2-3), the Planned Maintenance System is designed to simplify the scheduling of planned maintenance. All required planned maintenance actions are programmed throughout the overhaul cycle of a ship. In addition, the system is flexible enough to readily accommodate any changes in a ship's employment schedule.

The cycle schedule contains a list of the components for each division or maintenance group and indicates the quarter after overhaul in which the semiannual, annual, and overhaul cycle maintenance requirements are to be scheduled. The cycle schedule also lists the quarterly, monthly, and situation requirements that must be scheduled every quarter. The department head, in conjunction with division officers and leading petty officers, uses the cycle schedule in making out the quarterly schedule.

By definition, the day a ship leaves the shipyard is considered to be in the first quarter after overhaul. This day could conceivably be near the end of the quarter. A ship is not necessarily expected to perform all of the planned maintenance listed for the first quarter after overhaul, but the amount performed must be in proportion to the time remaining in that particular quarter. The steps to follow in using the cycle schedule can best be explained by reference to figure 2-3. Consider, for

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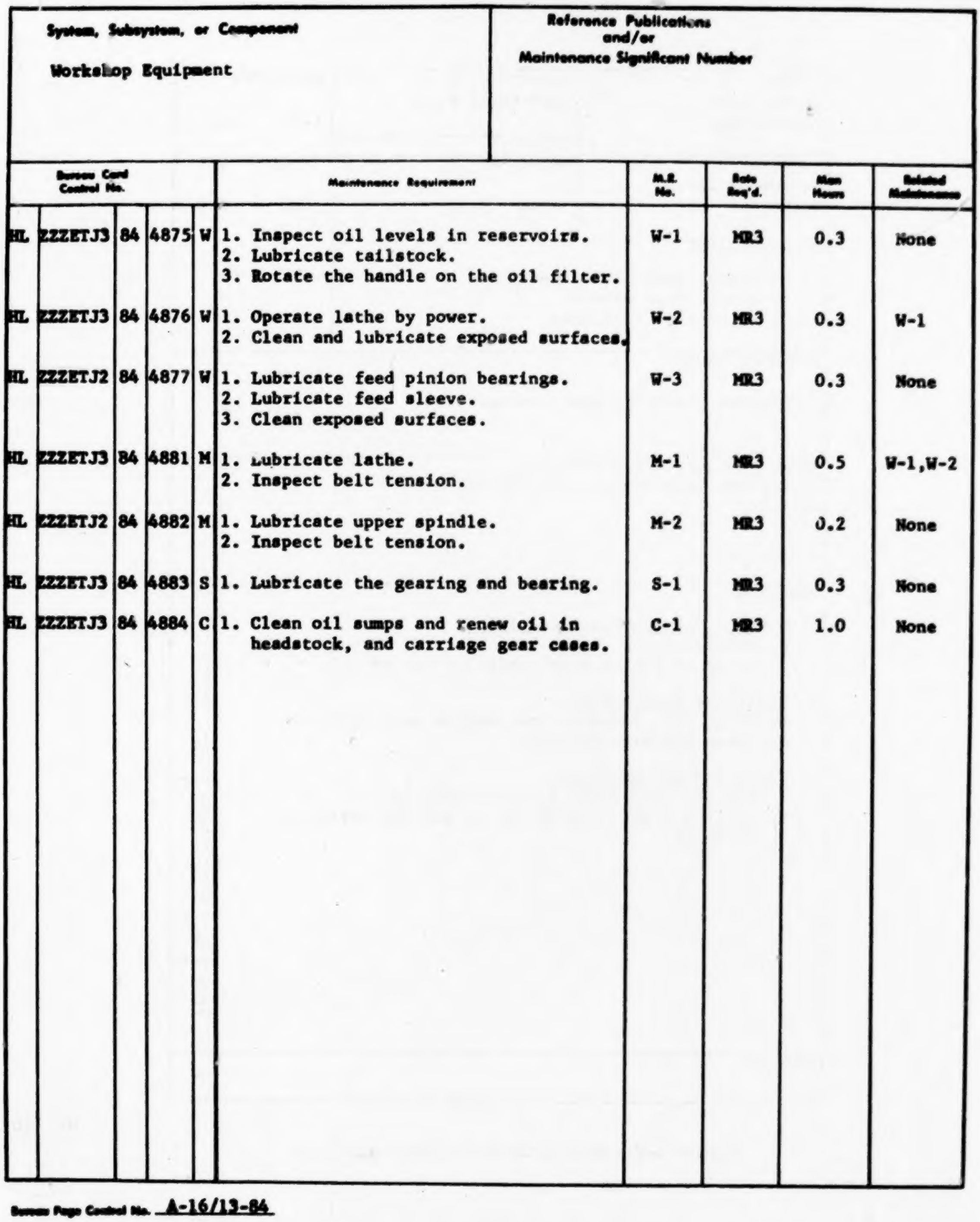


System, Subsystem, or Component

Workshop Equipment

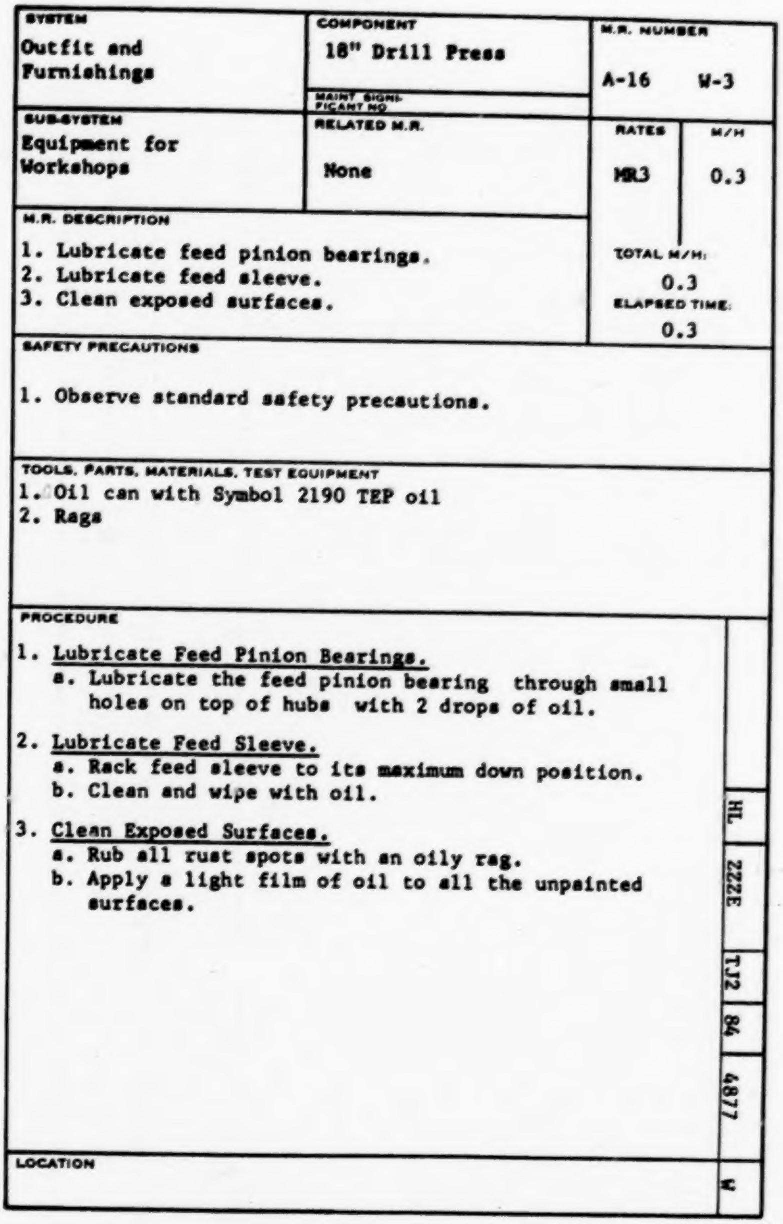
Reference Publications and/or Maintenance Significant Number

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
HL	ZZZETJ3	84	4875	W	1. Inspect oil levels in reservoirs. 2. Lubricate tailstock. 3. Rotate the handle on the oil filter.	W-1	MR3	0.3	None
HL	ZZZETJ3	84	4876	W	1. Operate lathe by power. 2. Clean and lubricate exposed surfaces.	W-2	MR3	0.3	W-1
HL	ZZZETJ2	84	4877	W	1. Lubricate feed pinion bearings. 2. Lubricate feed sleeve. 3. Clean exposed surfaces.	W-3	MR3	0.3	None
HL	ZZZETJ3	84	4881	M	1. Lubricate lathe. 2. Inspect belt tension.	M-1	MR3	0.5	W-1,W-2
HL	ZZZETJ2	84	4882	M	1. Lubricate upper spindle. 2. Inspect belt tension.	M-2	MR3	0.2	None
HL	ZZZETJ3	84	4883	S	1. Lubricate the gearing and bearing.	S-1	MR3	0.3	None
HL	ZZZETJ3	84	4884	C	1. Clean oil sumps and renew oil in headstock, and carriage gear cases.	C-1	MR3	1.0	None

Bureau Page Control No. A-16/13-84

98.171

Figure 2-1.—Maintenance Index Page.



SYSTEM Outfit and Furnishings	COMPONENT 18" Drill Press MAINT SIGNI-FICANT NO	M.R. NUMBER A-16 W-3
SUB-SYSTEM Equipment for Workshops	RELATED M.R. None	RATES MR3
		M/H 0.3

M.R. DESCRIPTION

1. Lubricate feed pinion bearings.
2. Lubricate feed sleeve.
3. Clean exposed surfaces.

TOTAL M/H: 0.3

ELAPSED TIME: 0.3

SAFETY PRECAUTIONS

1. Observe standard safety precautions.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Oil can with Symbol 2190 TEP oil
2. Rags

PROCEDURE

1. Lubricate Feed Pinion Bearings.
   a. Lubricate the feed pinion bearing through small holes on top of hubs with 2 drops of oil.
2. Lubricate Feed Sleeve.
   a. Rack feed sleeve to its maximum down position.
   b. Clean and wipe with oil.
3. Clean Exposed Surfaces.
   a. Rub all rust spots with an oily rag.
   b. Apply a light film of oil to all the unpainted surfaces.

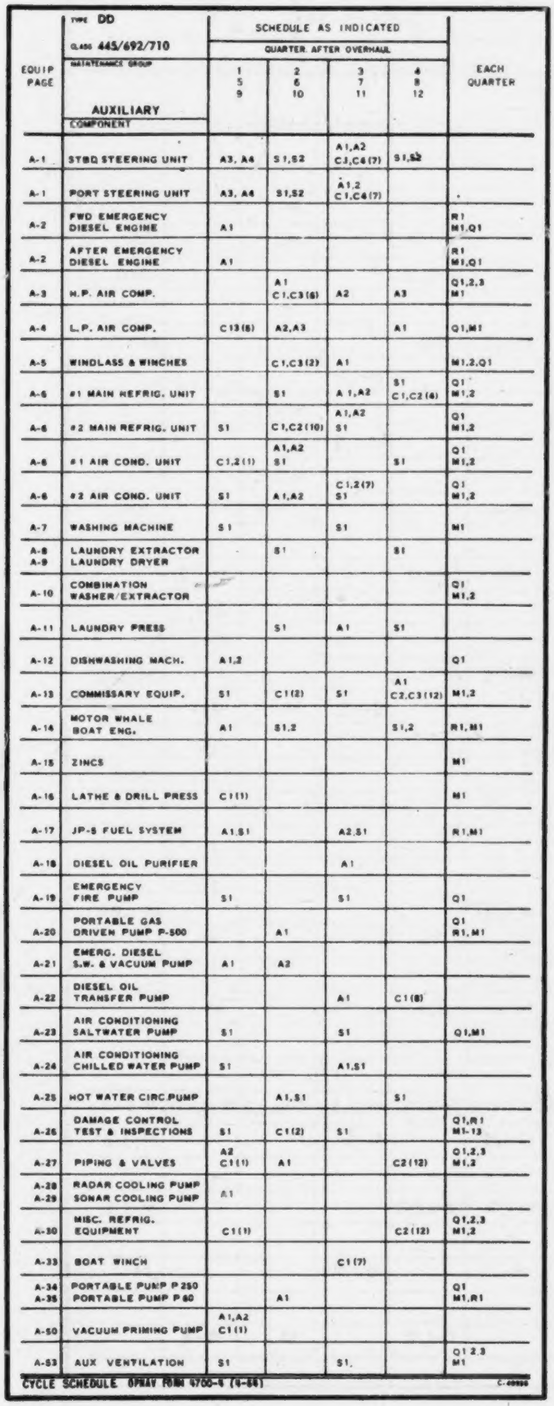
HL 3222 TJ2 84 4877

LOCATION

W

98.176

Figure 2-2.—Maintenance Requirement Card.



TYPE DD
CLASS 445/692/710
MAINTENANCE GROUP AUXILIARY

EQUIP PAGE	COMPONENT	SCHEDULE AS INDICATED QUARTER AFTER OVERHAUL				EACH QUARTER
		1 5 9	2 6 10	3 7 11	4 8 12	
A-1	STBD STEERING UNIT	A3, A4	S1,S2	A1,A2 C1,C4(7)	S1,S2	
A-1	PORT STEERING UNIT	A3, A4	S1,S2	A1,2 C1,C4(7)		
A-2	FWD EMERGENCY DIESEL ENGINE	A1				R1 M1,Q1
A-2	AFTER EMERGENCY DIESEL ENGINE	A1				R1 M1,Q1
A-3	H.P. AIR COMP.		A1 C1,C3(6)	A2	A3	Q1,2,3 M1
A-4	L.P. AIR COMP.	C13(5)	A2,A3		A1	Q1,M1
A-5	WINDLASS & WINCHES		C1,C3(2)	A1		M1,2,Q1
A-6	#1 MAIN REFRIG. UNIT		S1	A1,A2	S1 C1,C2(4)	Q1 M1,2
A-6	#2 MAIN REFRIG. UNIT	S1	C1,C2(10)	A1,A2 S1		Q1 M1,2
A-6	#1 AIR COND. UNIT	C1,2(1)	A1,A2 S1		S1	Q1 M1,2
A-6	#2 AIR COND. UNIT	S1	A1,A2	C1,2(7) S1		Q1 M1,2
A-7	WASHING MACHINE	S1		S1		M1
A-8 A-9	LAUNDRY EXTRACTOR LAUNDRY DRYER		S1		S1	
A-10	COMBINATION WASHER/EXTRACTOR					Q1 M1,2
A-11	LAUNDRY PRESS		S1	A1	S1	
A-12	DISHWASHING MACH.	A1,2				Q1
A-13	COMMISSARY EQUIP.	S1	C1(2)	S1	A1 C2,C3(12)	M1,2
A-14	MOTOR WHALE BOAT ENG.	A1	S1,2		S1,2	R1,M1
A-15	ZINCS					M1
A-16	LATHE & DRILL PRESS	C1(1)				M1
A-17	JP-5 FUEL SYSTEM	A1,S1		A2,S1		R1,M1
A-18	DIESEL OIL PURIFIER			A1		
A-19	EMERGENCY FIRE PUMP	S1		S1		Q1
A-20	PORTABLE GAS DRIVEN PUMP P-500		A1			Q1 R1,M1
A-21	EMERG. DIESEL S.W. & VACUUM PUMP	A1	A2			
A-22	DIESEL OIL TRANSFER PUMP			A1	C1(8)	
A-23	AIR CONDITIONING SALTWATER PUMP	S1		S1		Q1,M1
A-24	AIR CONDITIONING CHILLED WATER PUMP	S1		A1,S1		
A-25	HOT WATER CIRC.PUMP		A1,S1		S1	
A-26	DAMAGE CONTROL TEST & INSPECTIONS	S1	C1(2)	S1		Q1,R1 M1-13
A-27	PIPING & VALVES	A2 C1(1)	A1		C2(12)	Q1,2,3 M1,2
A-28 A-29	RADAR COOLING PUMP SONAR COOLING PUMP	A1				
A-30	MISC. REFRIG. EQUIPMENT	C1(1)			C2(12)	Q1,2,3 M1,2
A-33	BOAT WINCH			C1(7)		
A-34 A-35	PORTABLE PUMP P 250 PORTABLE PUMP P 60		A1			Q1 M1,R1
A-50	VACUUM PRIMING PUMP	A1,A2 C1(1)				
A-53	AUX VENTILATION	S1		S1.		Q1 2,3 M1

CYCLE SCHEDULE OPNAV FORM 4700-4 (4-66) [illegible]

98.172

Figure 2-3.—Cycle schedule.

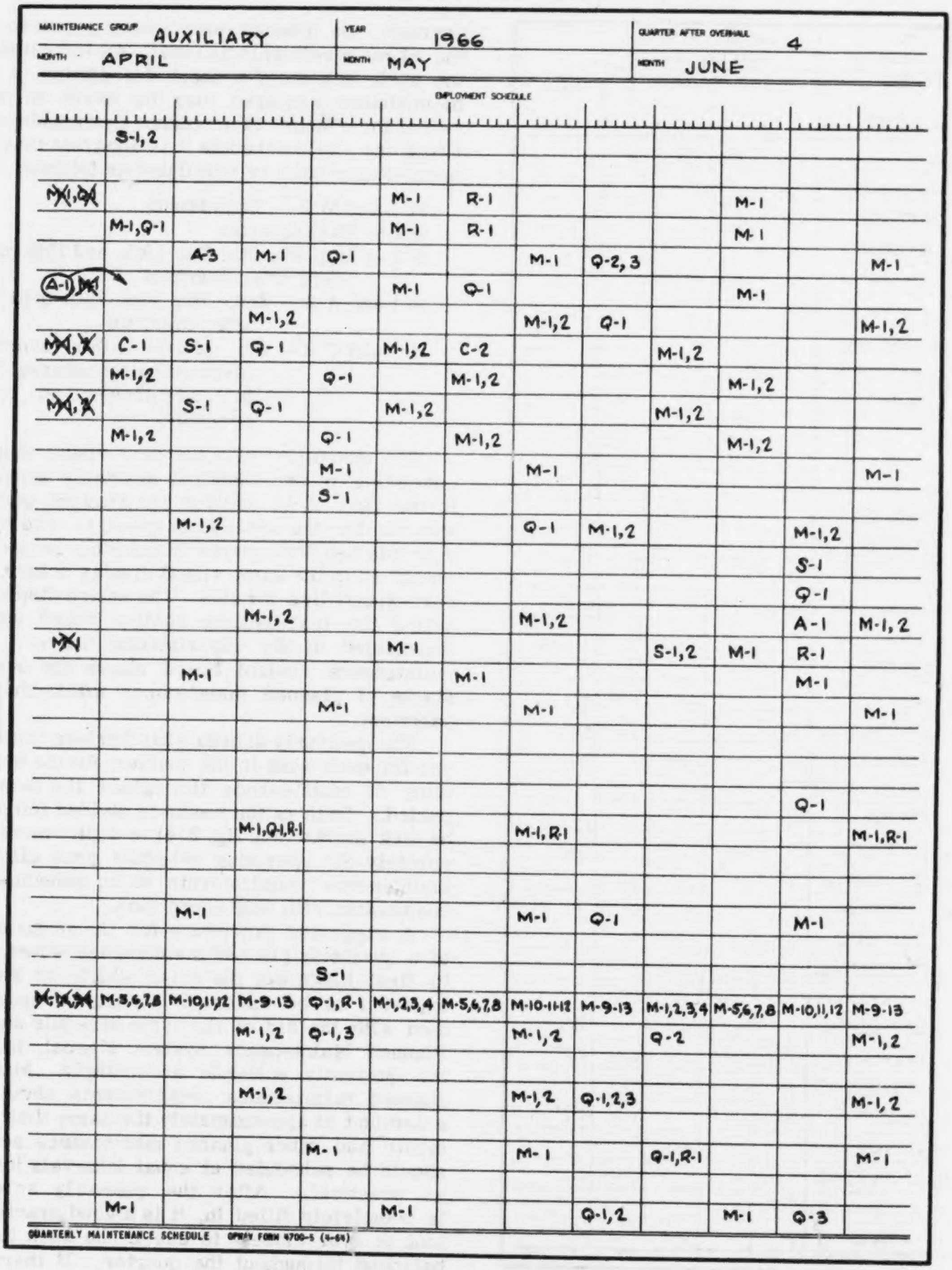
example, the planned maintenance required for the #1 main refrigeration unit. As indicated on the cycle schedule, a short description of the maintenance required may be found on page A-6 of the Planned Maintenance System Manual. From the cycle schedule it is apparent that the maintenance must be scheduled as follows:

M 1 and M 2 — Each Month
Q 1 — Each Quarter
S 1 — 2nd, 4th, 6th, 8th, 10th, and 12th quarters after overhaul
A 1 and A 2 — 3rd, 7th, and 11th quarters after overhaul
C 1 and C 2 — 4th quarter after overhaul (denoted by the numeral "4" in parentheses on cycle schedule)

The quarterly schedule is a visual display consisting of two identical quarterly schedule forms (fig. 2-4), one for the current quarter and one for the subsequent quarter. The cycle schedule and both quarterly schedule forms are contained in the same visual display holder, and correspond line for line. The entire display is called the maintenance control board and is maintained in the departmental office. The maintenance control board shows the overall status of planned maintenance within the department.

The quarterly schedule has thirteen columns, one for each week in the quarter, for the scheduling of maintenance throughout the 3-month period. Each of the weeks is divided into days by tick marks (see fig. 2-4) to depict more accurately the operating schedule, thus allowing maintenance requirements to be scheduled in conjunction with ship operations.

A suggested procedure for the preparation of a quarterly planned maintenance schedule is to first black out the dates which the ship is expected to be underway during the quarter, then with the aid of the cycle schedule and the Planned Maintenance System Manual, fill out the quarterly schedule accordingly. Monthly planned maintenance requirements should be scheduled at approximately the same time each month and other planned maintenance actions should be scheduled at equal intervals insofar as practical. After the quarterly schedule is completely filled in, it is a good practice to look it over closely to see if the work load is balanced throughout the quarter. If there appears to be less work scheduled during one week of the quarter than the others, some of the



MAINTENANCE GROUP AUXILIARY | YEAR 1966 | QUARTER AFTER OVERHAUL 4

MONTH APRIL | MONTH MAY | MONTH JUNE

EMPLOYMENT SCHEDULE

	S-1,2											
~~M-1,Q-1~~					M-1	R-1				M-1		
	M-1,Q-1				M-1	R-1				M-1		
		A-3	M-1	Q-1			M-1	Q-2,3				M-1
A-1 ~~M-1~~					M-1	Q-1				M-1		
			M-1,2				M-1,2	Q-1				M-1,2
~~M-1,2~~	C-1	S-1	Q-1		M-1,2	C-2			M-1,2			
	M-1,2			Q-1		M-1,2				M-1,2		
~~M-1,2~~		S-1	Q-1		M-1,2				M-1,2			
	M-1,2			Q-1		M-1,2				M-1,2		
				M-1			M-1					M-1
				S-1								
		M-1,2					Q-1	M-1,2			M-1,2	
											S-1	
											Q-1	
			M-1,2				M-1,2				A-1	M-1,2
~~M-1~~					M-1				S-1,2	M-1	R-1	
		M-1				M-1					M-1	
				M-1			M-1					M-1
											Q-1	
			M-1,Q-1,R-1				M-1,R-1					M-1,R-1
		M-1					M-1	Q-1			M-1	
				S-1								
~~M-1,2,3,4~~	M-5,6,7,8	M-10,11,12	M-9-13	Q-1,R-1	M-1,2,3,4	M-5,6,7,8	M-10-11-12	M-9-13	M-1,2,3,4	M-5,6,7,8	M-10,11,12	M-9-13
			M-1,2	Q-1,3			M-1,2		Q-2			M-1,2
			M-1,2				M-1,2	Q-1,2,3				M-1,2
				M-1			M-1		Q-1,R-1			M-1
	M-1				M-1			Q-1,2		M-1	Q-3	

QUARTERLY MAINTENANCE SCHEDULE OPNAV FORM 4700-5 (4-64)

Figure 2-4.—Quarterly schedule.

98.173

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maintenance requirements should be rescheduled to balance the work load throughout the quarter.

The quarterly schedule is updated weekly. The leading petty officer of the division or maintenance group will cross out all maintenance requirements which have been accomplished and will circle all requirements which have not been accomplished. All circled requirements are rescheduled by drawing an arrow to a later week, as indicated in figure 2-4.

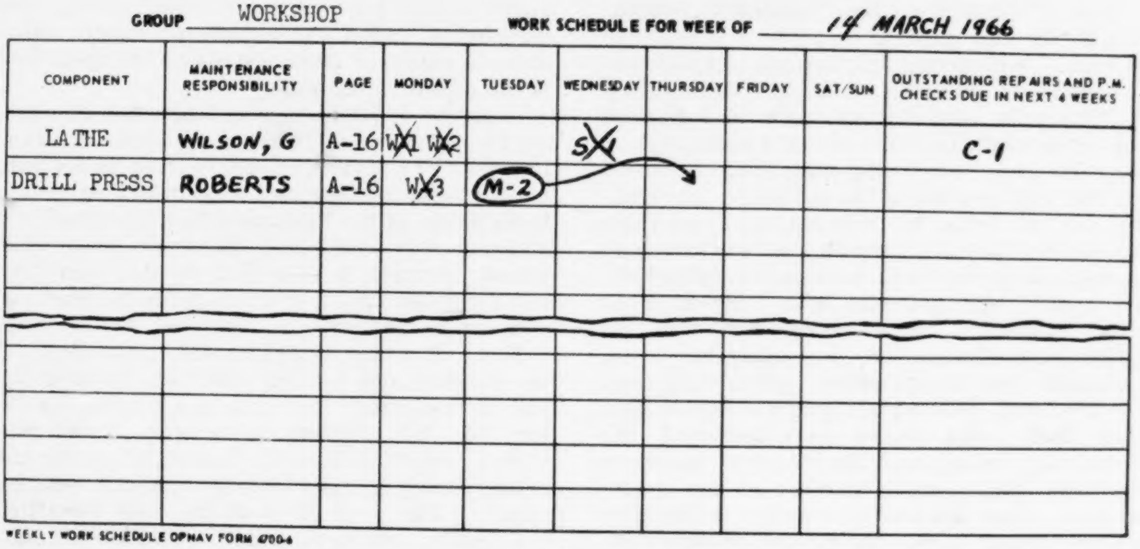
The quarterly schedule is kept on board as a record of all completed maintenance actions. This record may be destroyed at the beginning of the second quarter following the next shipyard overhaul period.

The quarterly schedule is also used by the leading petty officer of each division or maintenance group to prepare a weekly planned maintenance schedule (fig. 2-5). The weekly schedule is posted in each working space and is used by the leading petty officer to assign specific maintenance tasks to specific personnel.

The weekly schedule provides a list of the components, the appropriate page number of the Planned Maintenance System Manual, and spaces for the assignment of maintenance tasks to specific personnel. The daily and weekly planned maintenance actions are preprinted on the weekly schedule forms. All other planned maintenance requirements which are to be performed during a specific week are obtained from the current quarterly schedule.

The preparation of a weekly planned maintenance schedule requires you to take into consideration the available manpower, the time involved in each maintenance task, and the ship's operations. In the assignment of specific personnel to maintenance tasks, it must be remembered that the average time required to perform a task, as listed on the Maintenance Index Page and the Maintenance Requirement Card, does not take into account the time required to assemble the tools and materials to do the maintenance action nor the time required to clean the area and put away the tools at the end of the task. Related maintenance requirements (see fig. 2-1) which are due should be scheduled and performed together to conserve time. Any corrective maintenance, cleaning, and upkeep to be performed is in addition to the planned maintenance prescribed by the Planned Maintenance System.

The weekly schedule offers flexibility for all planned maintenance actions except those which must be performed daily. When a planned maintenance task is completed, the leading petty officer will cross out the requirement on the



GROUP WORKSHOP WORK SCHEDULE FOR WEEK OF 14 MARCH 1966

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN	OUTSTANDING REPAIRS AND P.M. CHECKS DUE IN NEXT 4 WEEKS
LATHE	WILSON, G	A-16	~~W-1~~ ~~W-2~~		~~S-1~~				C-1
DRILL PRESS	ROBERTS	A-16	~~W-3~~	M-2					

WEEKLY WORK SCHEDULE OPNAV FORM 4700-6

98.175

Figure 2-5.—Weekly schedule.

schedule. Maintenance that cannot be completed on schedule is circled and rescheduled on the basis of workload and ship operations.

The weekly schedule is designed for convenient preparation and effective reuse. At the end of each week, the leading petty officer of the division or maintenance group will take the weekly schedule to the departmental office, update the quarterly schedule, erase the weekly schedule, and prepare a schedule for the following week.

Feedback Report

The Planned Maintenance System allows for the correction of discrepancies in the system through the use of a Feedback Report (fig. 2-6). If a discrepancy exists in the system as installed aboard your ship, a Feedback Report should be originated immediately by the person who discovers the discrepancy.

The Feedback Report will be useful only if it contains all of the correct information concerning the discrepancy, including the reason for the recommended change. Prior to being forwarded, a Feedback Report should be checked for completeness and accuracy by the leading petty officer of the division.

RECORDING OF MAINTENANCE ACTIONS

The Maintenance Data Collection System (MDCS) is designed to provide a means of recording information concerning planned and corrective maintenance actions. Maintenance performed is recorded by code in sufficient detail to permit the collection of a great variety of information concerning maintenance actions and the performance of the equipment involved. The use of codes in recording and reporting maintenance actions permits machine processing with automatic data processing equipment. The system also provides data concerning the initial discovery of a malfunction, how the equipment malfunctioned, how many hours the equipment was in operation, which equipment was involved, what repair parts and materials were used, what delays were incurred, the reasons for delay, and the technical specialty or work center which performed the maintenance. Each maintenance action is reported in this manner except for routine preservation actions (chipping, painting, and cleaning) and daily or weekly Planned Maintenance System actions.

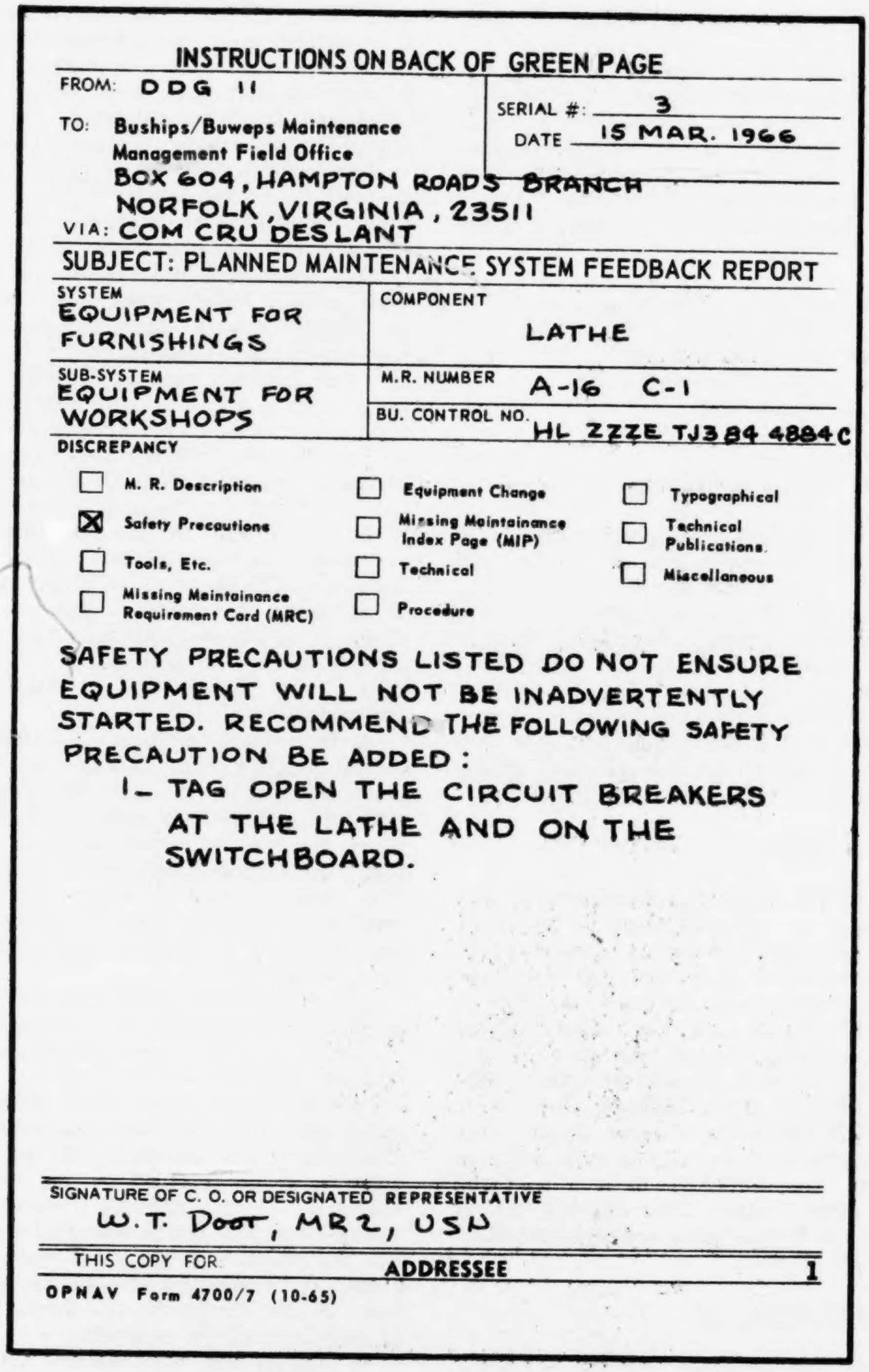
The shipboard installation of the Maintenance Data Collection System includes a central, functional data collection center. The primary function of the shipboard data collection center is to screen all documents for completeness and accuracy before they are forwarded to the data processing center. During the screening process, the data collection center adds a 4-digit maintenance control number in block 3 of each document.

The effectiveness of the Maintenance Data Collection System depends initially upon the individual performing the maintenance action and the accuracy with which it is reported. Leading petty officers are responsible for ensuring that all forms used in connection with the Maintenance Data Collection System are complete and accurate. Leading petty officers should also ensure that a form is submitted for each applicable action and that no action is reported more than once.

Equipment Identification Code Manual

It is essential that all personnel having any responsibility for maintenance actions be indoctrinated in the proper use of the Equipment Identification Code Manual as it contains many of the codes used in the reporting of maintenance actions. Each major system is coded and the codes are broken down to the lowest part necessary for positive equipment identification. The manner in which the equipment identification code is obtained from the manual is described in the following example.

Assume it is desired to determine the code for the casing wearing rings and impeller wearing rings of a main condensate pump in a steam main propulsion system. By referring to the index pages of the Equipment Identification Code Manual, it is found that the steam main propulsion system is identified by the code "Z" and the subsystem (in this example the feed and condensate system) is identified by the code "ZQ". The next step is to turn to the pages of the manual with the ZQ codes and go down the list of equipment until you come to the listing for the main condensate pump. Under this listing you will find the 7-digit codes for the casing wearing rings and the impeller wearing rings. The first digit of the code identifies the system, the second digit identifies the subsystem, the third and fourth digits identify the equipment and the last three digits identify the assembly. If the assembly requires further



INSTRUCTIONS ON BACK OF GREEN PAGE

FROM: DDG 11

SERIAL #: 3

DATE 15 MAR. 1966

TO: **Buships/Buweps Maintenance**
Management Field Office
BOX 604, HAMPTON ROADS BRANCH
NORFOLK, VIRGINIA, 23511

VIA: COM CRU DESLANT

SUBJECT: PLANNED MAINTENANCE SYSTEM FEEDBACK REPORT

SYSTEM
EQUIPMENT FOR FURNISHINGS

COMPONENT
LATHE

SUB-SYSTEM
EQUIPMENT FOR WORKSHOPS

M.R. NUMBER A-16 C-1

BU. CONTROL NO. HL ZZZE TJ3 84 4884C

DISCREPANCY

☐ **M. R. Description**
☒ **Safety Precautions**
☐ **Tools, Etc.**
☐ **Missing Maintainance Requirement Card (MRC)**
☐ **Equipment Change**
☐ **Missing Maintainance Index Page (MIP)**
☐ **Technical**
☐ **Procedure**
☐ **Typographical**
☐ **Technical Publications.**
☐ **Miscellaneous**

SAFETY PRECAUTIONS LISTED DO NOT ENSURE EQUIPMENT WILL NOT BE INADVERTENTLY STARTED. RECOMMEND THE FOLLOWING SAFETY PRECAUTION BE ADDED:

1- TAG OPEN THE CIRCUIT BREAKERS AT THE LATHE AND ON THE SWITCHBOARD.

SIGNATURE OF C. O. OR DESIGNATED REPRESENTATIVE
W.T. Door, MR2, USN

THIS COPY FOR **ADDRESSEE** **1**

OPNAV Form 4700/7 (10-65)

40.101

Figure 2-6.—Planned Maintenance System Feedback Report.

breakdown, the last digit identified the subassembly.

In addition to the equipment identification codes, the Equipment Identification Code Manual contains other codes and information of equal importance. Section I of the manual contains general instructions for the preparation of forms when reporting maintenance actions. Other sections of the manual contain additional codes as follows:

Section II	Administrative Organization
Section III	Work Center
Section IV	How Malfunctioned
Section V	When Discovered
Section VI	Action Taken
Section VII	Service
Section VIII	Source
Section IX	Type Availability

These codes make possible the recording of a wide variety of information in a relatively small space. At the data processing level, the codes permit use of automatic data processing operations which provide pertinent, direct-reading, information summaries. The summaries can be profitably employed only if accurate information has been recorded; therefore familiarity with the coding systems is a must and the importance of accuracy in the recording of codes cannot be overstressed.

MDCS Documentation

Documentation in the Maintenance Data Collection System is accomplished by the completion, as applicable, of one or more standard forms. Forms used to record and report information related to maintenance actions aboard ship and within repair activities include OPNAV Form 4700-2B (Shipboard Maintenance Action), OPNAV Form 4700-2D (Deferred Action), OPNAV Form 4700-2C (Work Request), and OPNAV Form 4700-2F (Work Supplement Card). Detailed descriptions of the entries to be made on these forms are listed in Section I of the Equipment Identification Code Manual and in chapter 3 of the Maintenance and Material Management (3-M) Manual.

Management (3-M) Manual

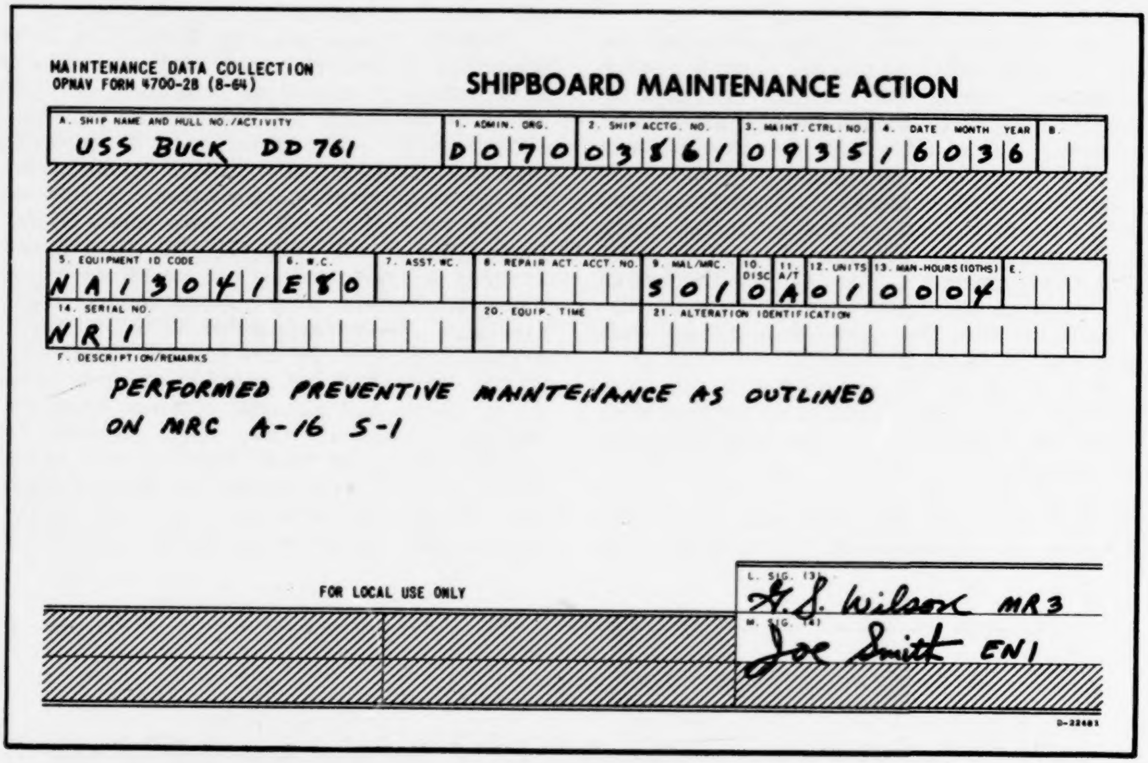
Shipboard Maintenance Action Form.—A sample Shipboard Maintenance Action Form (OPNAV 4700-2B) is shown in figure 2-7. This form is a single-sheet document used to record the completion of planned maintenance actions, corrective maintenance actions, and authorized alterations that have been performed at the shipboard level by shipboard personnel. All planned maintenance actions except daily and weekly actions must be recorded on this form, as well as on the weekly and quarterly schedules. Routine preservation such as chipping, painting, and cleaning should not be reported.

The Shipboard Maintenance Action Form is also used to report work done aboard ship by an outside activity which does not report under the Maintenance Data Collection System. When a repair activity such as a civilian contractor or a shipyard (except for regular overhauls) which is not under the Maintenance Data Collection System provides ship maintenance assistance, duplicate 4700-2B documents are prepared. Block 7 of the original document is left blank and the code for the assisting work center is entered on the duplicate. Only those manhours actually spent by the shipboard personnel in assisting the outside activity are entered in block 13 of the original; manhours spent by the outside activity in assisting the shipboard work center are documented in block 13 of the duplicate.

Deferred Action Form.—The Deferred Action Form (OPNAV 4700-2D) is a two-sheet form used to report corrective maintenance actions that are deferred because of the ship's operations, the lack of repair parts, or the requirement for outside assistance. The first sheet (fig. 2-8) is used to record and report the reason for deferral and the second sheet (fig. 2-9) is used to report the completion of the deferred action.

If a corrective maintenance action is beyond ship's force capability and outside assistance is required, a work request is prepared and forwarded. This situation will always require that an OPNAV Form 4700-2D be submitted. The manhours that have been expended, if any, by ship's force in connection with the maintenance action are documented on the OPNAV Form 4700-2D. The manhours involved in the investigation and the removal of the equipment are documented on the first sheet of the document. The manhours involved in the reinstallation of the equipment are documented on the second sheet of the document.

If a shipboard maintenance action must be deferred due to the lack of necessary repair parts or because of the ship's operations, an



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2B (8-64)

SHIPBOARD MAINTENANCE ACTION

A. SHIP NAME AND HULL NO./ACTIVITY: USS BUCK DD 761
1. ADMIN. ORG.: D070
2. SHIP ACCTG. NO.: 03861
3. MAINT. CTRL. NO.: 0935
4. DATE MONTH YEAR: 16036
B.:
5. EQUIPMENT ID CODE: NA13041
6. W.C.: E80
7. ASST. WC.:
8. REPAIR ACT. ACCT. NO.:
9. MAL/MRC.: S01
10. DISC: 0
11. A/T: A
12. UNITS: 01
13. MAN-HOURS (10THS): 0004
E.:
14. SERIAL NO.: NR1
20. EQUIP. TIME:
21. ALTERATION IDENTIFICATION:
F. DESCRIPTION/REMARKS: PERFORMED PREVENTIVE MAINTENANCE AS OUTLINED ON MRC A-16 S-1

FOR LOCAL USE ONLY

L. SIG. (3): G. S. Wilson MR3
M. SIG. (4): Joe Smith EN1

D-22483

17.81B

Figure 2-7.—Shipboard Maintenance Action Form.

OPNAV Form 4700-2D is prepared and the first sheet is submitted (using the appropriate action taken code from section VI of the Equipment Identification Code Manual) and the manhours expended, if any, are entered in block 13. When the maintenance action is completed, the second sheet is submitted using the appropriate action taken code and the manhours expended in completing the action are entered in block 13.

Work Request.—The Work Request Form (OPNAV 4700-2C) is a four-sheet document which is presently used to request outside assistance from repair ships and tenders. It is planned that OPNAV 4700-2C will also be used, at a later date, for requesting assistance from shipyards. Part I of the work request is shown in figure 2-10. Part II of the work request, shown in figure 2-11, is a continuation of part I and provides additional space for written descriptions, diagrams, and sketches.

The information to be given in block F (Description/Remarks) of the work request includes the name of the component, the CID number of the component, and the alteration number. If the alteration number is not applicable (N/A), it must be so indicated (see fig. 2-10). Block F should also contain a description of the existing defects and the repairs required on the component.

Sheet 1 of the work request is retained by the requesting activity and sheets 2, 3, and 4 are forwarded to the assigned repair activity via the designated chain of command. Information concerning the administrative procedures to be followed by repair activities may be found in chapter 4 of the Maintenance and Material Management (3-M) Manual.

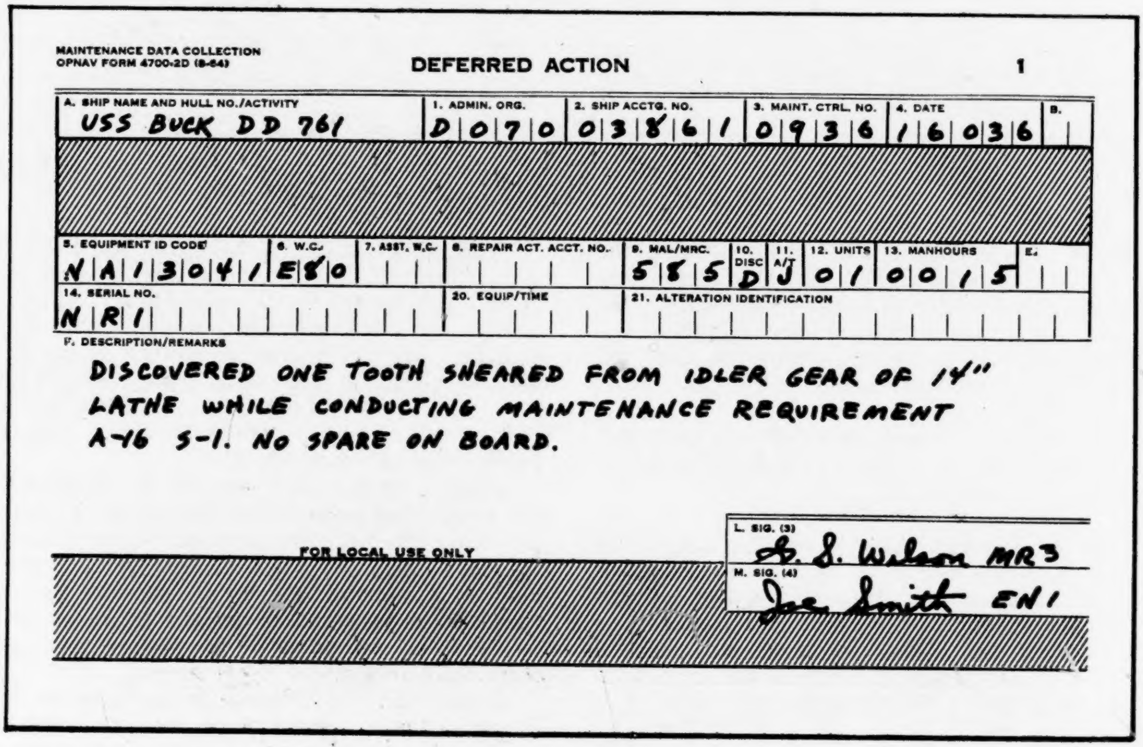
When the work request is accepted by the repair activity, sheet 3 of the document is used as a job order and is sent to the assigned work center. Prepunched Work Supplement Cards (OPNAV 4700-2F) are also sent to the assigned work center. A sample OPNAV 4700-2F is shown in figure 2-12.

The assigned work center performs the job, records the maintenance data on Work Supplement Cards, and records the material obtained outside of normal supply channels on the reverse side of the card. If more than one workday is required to complete the action, or if assisting work centers are needed, the lead work center will utilize the additional Work Supplement Cards provided to record daily manhours expended. (The lead work center is that work center which has the primary responsibility for the completion of the task described on the work request.)

When a repair job is completed, sheet 3 of the work request is completed by the lead work center and is signed by the man who performed the maintenance. An inspector from the requesting activity is contacted for final inspection and signs off the work request. After obtaining the signature of the inspector, the lead work center supervisor forwards the completed work request to his division officer.

Material Usage and Cost Data.—The documentation of material usage and cost data on maintenance transactions requires the joint effort of the supply and maintenance personnel aboard ship. The form used to document material usage and cost data is determined by the action involved and the source of material.

The reverse side of the appropriate OPNAV form (OPNAV 4700-2B, 4700-2D, or 4700-2F) is used by maintenance personnel to report material obtained from outside normal supply channels. The reverse sides of OPNAV Forms 4700-2D and 4700-2F are essentially the same as the Form 4700-2B which is shown in figure 2-13. Parts and material obtained from pre-expended material bins; items obtained by cannibalization or from salvage, that can be identified by a part number or stock number; and consumable materials, such as lumber, sheet metal, and bar stock, used for manufacture



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION

1

A. SHIP NAME AND HULL NO./ACTIVITY: USS BUCK DD 761
1. ADMIN. ORG.: D070
2. SHIP ACCTG. NO.: 03861
3. MAINT. CTRL. NO.: 0936
4. DATE: 16036
B.:
5. EQUIPMENT ID CODE: NA13041
6. W.C.: E80
7. ASST. W.C.:
8. REPAIR ACT. ACCT. NO.:
9. MAL/MRC.: 585
10. DISC: D
11. A/T: J
12. UNITS: 01
13. MANHOURS: 0015
E.:
14. SERIAL NO.: NR1
20. EQUIP/TIME:
21. ALTERATION IDENTIFICATION:

F. DESCRIPTION/REMARKS

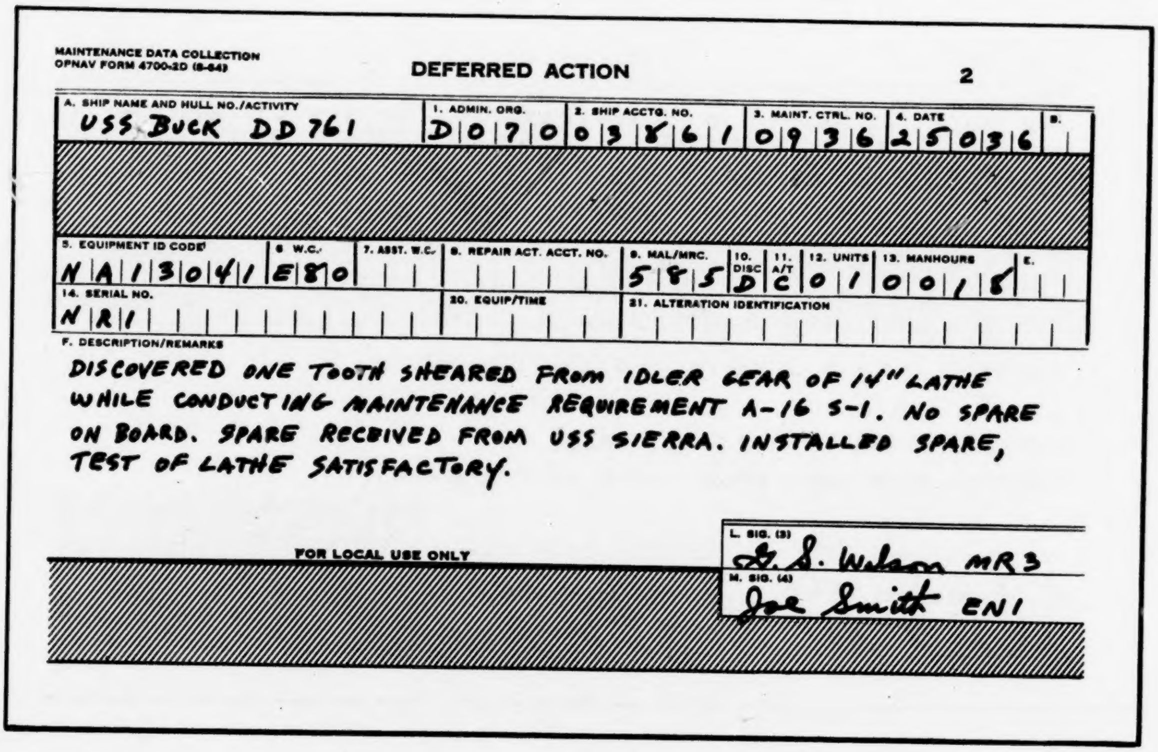
DISCOVERED ONE TOOTH SHEARED FROM IDLER GEAR OF 14" LATHE WHILE CONDUCTING MAINTENANCE REQUIREMENT A-16 5-1. NO SPARE ON BOARD.

FOR LOCAL USE ONLY

L. SIG. (3) S. S. Wilson MR3
M. SIG. (4) Joe Smith EN1

17.81D

Figure 2-8.—Deferred Action Form, Sheet 1.



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION 2

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE	B.
USS BUCK DD 761	D070	03861	0936	25036	

5. EQUIPMENT ID CODE	6 W.C.	7. ASST. W.C.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MANHOURS	E.
NA13041	E80			585	D	C	01	0018	

14. SERIAL NO.	20. EQUIP/TIME	21. ALTERATION IDENTIFICATION
NR1		

F. DESCRIPTION/REMARKS

DISCOVERED ONE TOOTH SHEARED FROM IDLER GEAR OF 14" LATHE WHILE CONDUCTING MAINTENANCE REQUIREMENT A-16 S-1. NO SPARE ON BOARD. SPARE RECEIVED FROM USS SIERRA. INSTALLED SPARE, TEST OF LATHE SATISFACTORY.

FOR LOCAL USE ONLY

L. SIG. (3) G. S. Wilson MR3

M. SIG. (4) Joe Smith EN1

Figure 2-9.—Deferred Action Form, Sheet 2.

17.81D

work are reported. Economy of effort and the elimination of duplicate recording are highly desirable; however, when there is doubt about reporting an item, it should be reported.

Existing supply forms are used to document the material usage and cost data of repair parts or materials obtained through the normal supply channels. The document used is determined by the availability of automatic data processing equipment. If the ship has automatic data processing equipment, DD Form 1348 is used. If the ship does not have automatic data processing equipment, NAVSANDA Form 1250 is used. Maintenance personnel are required to furnish the work center code, the equipment identification code, the CID number, the maintenance control number, the name of the part, and the stock number when submitting the Form 1250 or the Form 1348 to the supply department.

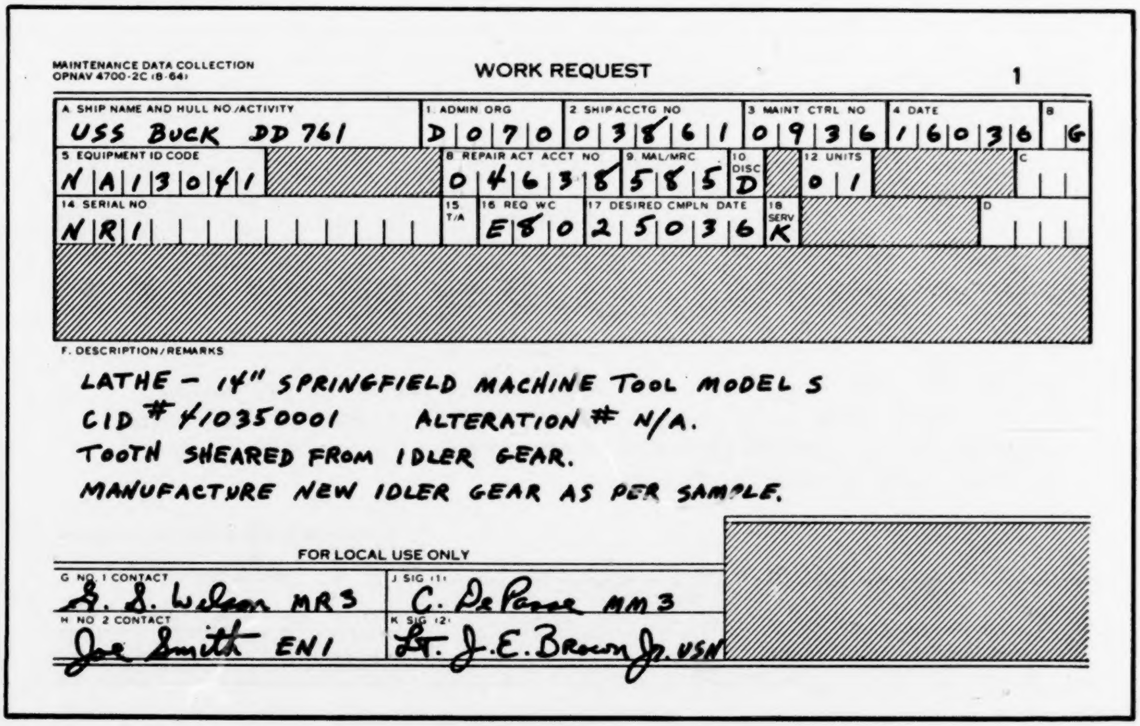
MANHOUR ACCOUNTING SYSTEM

The Manhour Accounting System, sometimes referred to as Exception Time Accounting (ETA), is designed and intended for use by the repair department of repair activities in conjunction with the Maintenance Data Collection System. It is basically a management tool and accounts for deviations from a normal 7-hour working day.

The mechanics of Exception Time Accounting include the use of codes, the preparation of a Master Roster Listing, and the preparation and submission of Daily Exception Cards (OPNAV Form 4700-2E). A sample Daily Exception Card is shown in figure 2-14.

ETA Codes

Exception Time Accounting codes identify work centers, pay grades of individuals, work assignments, and the categories of manhour



MAINTENANCE DATA COLLECTION
OPNAV 4700-2C (8-64)

WORK REQUEST

1

A SHIP NAME AND HULL NO./ACTIVITY	USS BUCK DD 761
1 ADMIN ORG	D070
2 SHIP ACCTG NO	03861
3 MAINT CTRL NO	0936
4 DATE	16036
B	G
5 EQUIPMENT ID CODE	NA13041
8 REPAIR ACT ACCT NO	04638
9 MAL/MRC	585
10 DISC	D
12 UNITS	01
C	
14 SERIAL NO	NR1
15 T/A	
16 REQ WC	E80
17 DESIRED CMPLN DATE	25036
18 SERV	K
D	

F. DESCRIPTION/REMARKS

LATHE – 14" SPRINGFIELD MACHINE TOOL MODEL S
CID # 410350001 ALTERATION # N/A.
TOOTH SHEARED FROM IDLER GEAR.
MANUFACTURE NEW IDLER GEAR AS PER SAMPLE.

FOR LOCAL USE ONLY

G NO. 1 CONTACT	S. S. Wilson MR3
J SIG (1)	C. DePasse MM3
H NO 2 CONTACT	Joe Smith EN1
K SIG (2)	Lt. J.E. Brown Jr. USN

17.81C

Figure 2-10.—Work Request, Part I.

expenditures for each person reported in the system.

The work center codes listed in section III of the Equipment Identification Code Manual are used. These codes are entered in block A of the Daily Exception Card.

Grade codes are assigned to all personnel from E-1 through captain. These codes may be found in chapter 5 of the Maintenance and Material Management (3-M) Manual and are entered in block C of the Daily Exception Card.

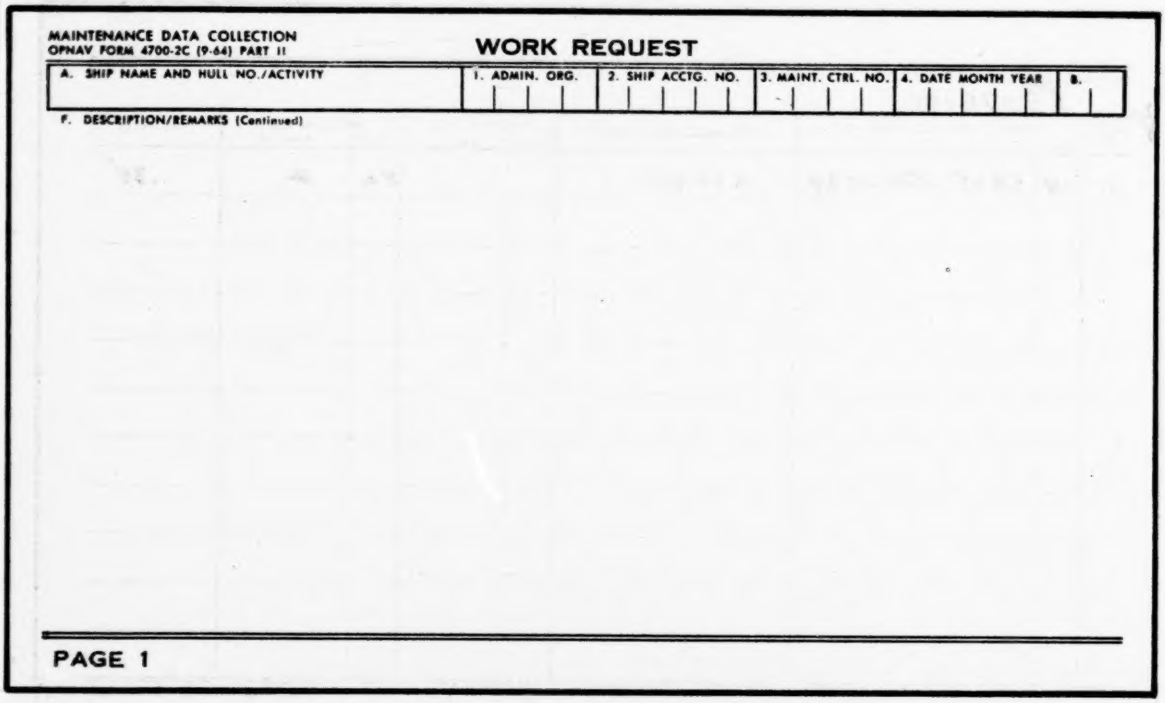
Labor codes are used to identify areas where manhours are being expended, and to what extent. Labor codes are divided into three major categories: Productive, Productive Support, and Nonproductive. Labor subcodes are also used to enable the maintenance manager to isolate areas where excessive manhours are being expended. The codes and subcodes for the major labor code groupings are listed on the reverse side of the Daily Exception Card.

Master Roster Listing

The number of manhours assigned to a work center for any given reporting period is established by the use of the Master Roster Listing. A reporting period for the Manhour Accounting System is one month.

Each work center prepares an initial roster of assigned personnel listing work center code, name grade code, and assigned labor code of each individual. The roster is screened for completeness and accuracy and then forwarded to Data Services. Data Services prepares a Master Roster Card Deck from the information contained in the listing. From this deck, Data Services provides each work center with a Master Roster Listing.

Each work center supervisor verifies the completeness and accuracy of the listing. Corrections are made by drawing a red line through the entry in error and inserting correct information above the incorrect item. The roster is resubmitted to Data Services and the



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2C (9-64) PART II

WORK REQUEST

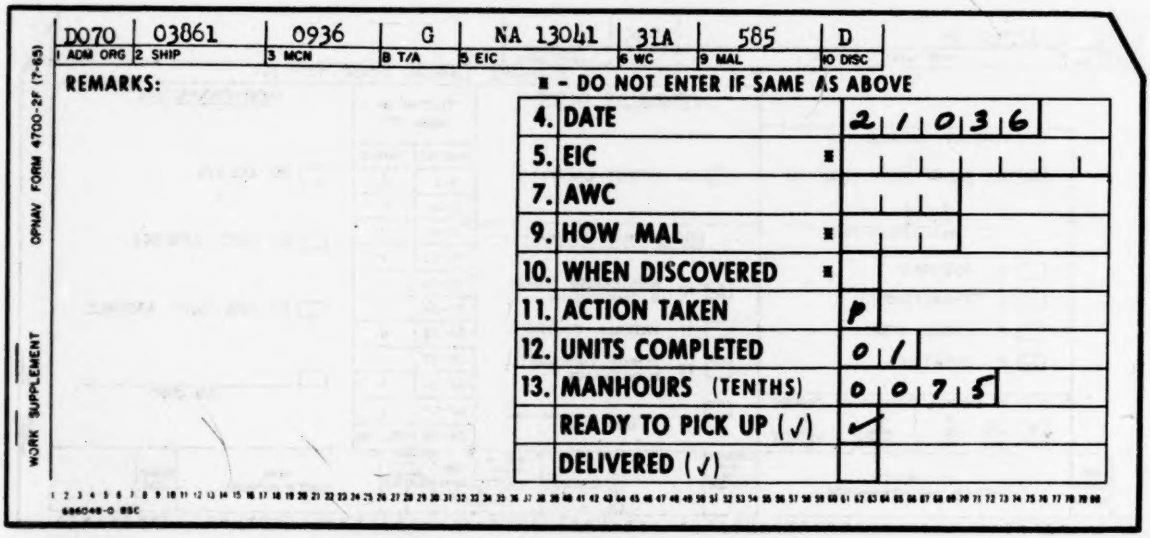
A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE MONTH YEAR	B.

F. DESCRIPTION/REMARKS (Continued)

PAGE 1

17.81C

Figure 2-11.—Work Request, Part II.



OPNAV FORM 4700-2F (7-65)

WORK SUPPLEMENT

D070	03861	0936	G	NA 13041	31A	585	D
1 ADM ORG	2 SHIP	3 MCN	8 T/A	5 EIC	6 WC	9 MAL	10 DISC

REMARKS:

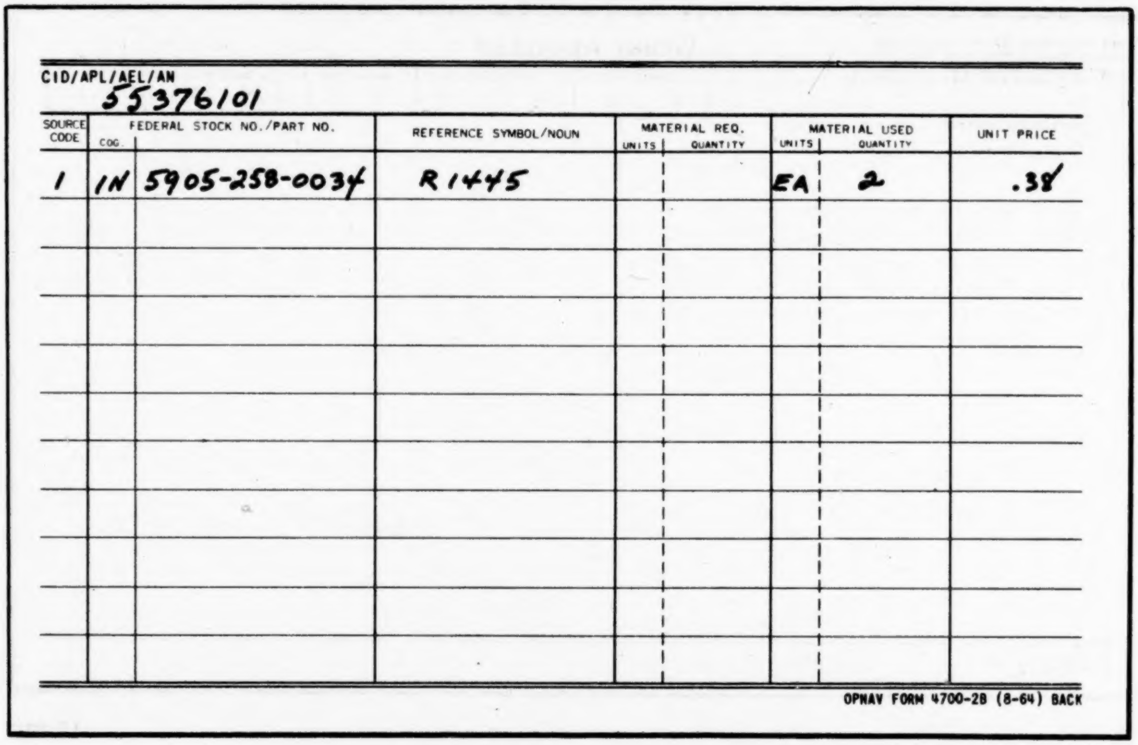
■ - DO NOT ENTER IF SAME AS ABOVE

4.	DATE	2 1 0 3 6
5.	EIC ■	
7.	AWC	
9.	HOW MAL ■	
10.	WHEN DISCOVERED ■	
11.	ACTION TAKEN	P
12.	UNITS COMPLETED	0 1
13.	MANHOURS (TENTHS)	0 0 7 5
	READY TO PICK UP (✓)	✓
	DELIVERED (✓)	

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
686048-0 BSC

17.81F

Figure 2-12.—Work Supplement Card.



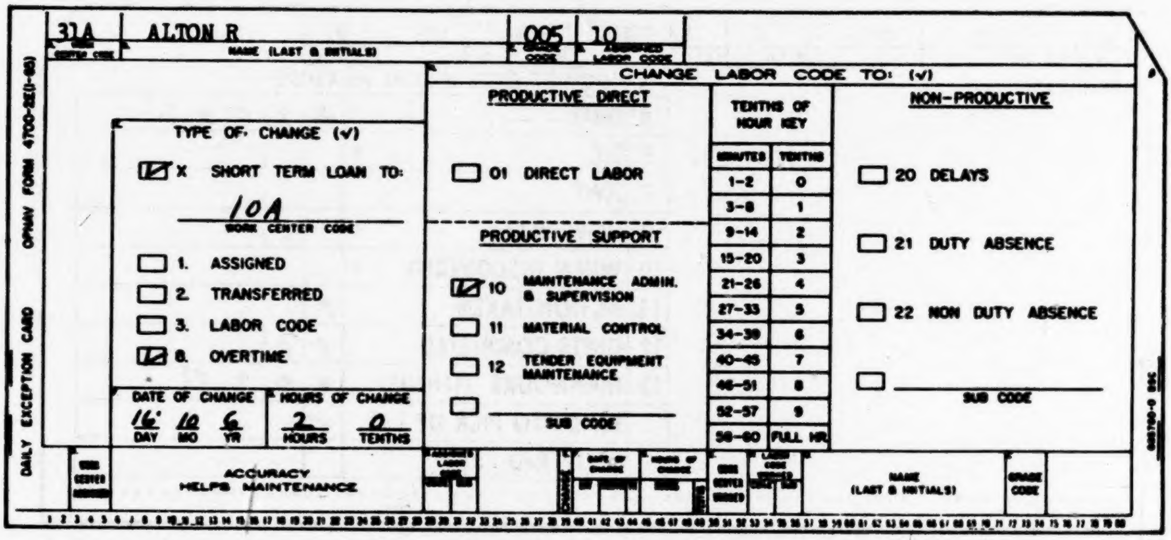
CID/APL/AEL/AN
55376101

SOURCE CODE	COG.	FEDERAL STOCK NO./PART NO.	REFERENCE SYMBOL/NOUN	MATERIAL REQ. UNITS	MATERIAL REQ. QUANTITY	MATERIAL USED UNITS	MATERIAL USED QUANTITY	UNIT PRICE
1	1N	5905-258-0034	R1445			EA	2	.38

OPNAV FORM 4700-2B (8-64) BACK

17.81B

Figure 2-13.—Reverse side of OPNAV 4700-2B.



DAILY EXCEPTION CARD OPNAV FORM 4700-2E(1-65)

31A WORK CENTER CODE
ALTON R NAME (LAST & INITIALS)
005 GRADE CODE
10 ASSIGNED LABOR CODE

TYPE OF CHANGE (✓)

☑ X SHORT TERM LOAN TO:
10A WORK CENTER CODE

☐ 1. ASSIGNED
☐ 2. TRANSFERRED
☐ 3. LABOR CODE
☑ 8. OVERTIME

DATE OF CHANGE
16 DAY 10 MO 6 YR

HOURS OF CHANGE
2 HOURS 0 TENTHS

CHANGE LABOR CODE TO: (✓)

PRODUCTIVE DIRECT

☐ 01 DIRECT LABOR

PRODUCTIVE SUPPORT

☑ 10 MAINTENANCE ADMIN. & SUPERVISION
☐ 11 MATERIAL CONTROL
☐ 12 TENDER EQUIPMENT MAINTENANCE
☐ ______ SUB CODE

TENTHS OF HOUR KEY

MINUTES	TENTHS
1-2	0
3-8	1
9-14	2
15-20	3
21-26	4
27-33	5
34-39	6
40-45	7
46-51	8
52-57	9
58-60	FULL HR

NON-PRODUCTIVE

☐ 20 DELAYS
☐ 21 DUTY ABSENCE
☐ 22 NON DUTY ABSENCE
☐ ______ SUB CODE

ACCURACY HELPS MAINTENANCE

NAME (LAST & INITIALS)

GRADE CODE

17.81E

Figure 2-14.—Daily Exception Card.

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Master Roster Deck of cards is corrected, if necessary. The completeness and accuracy of the Master Roster Listing is verified in the above manner at the end of each reporting period.

Daily Exception Card

After the cards in the Master Deck are verified, Data Services provides each work center supervisor with 25 Daily Exception Cards for each individual on the roster. The prepunched and machine printed cards reflect the individual's work center code, name, grade code, and assigned labor code.

The submission of a Daily Exception Card is required at any time a person is absent from his assigned work area in excess of 20 minutes. Information to be entered on the card includes the date, the amount of time involved in the exception, and appropriate labor codes and subcodes. When the exception is longer than the scheduled work shift, the card is completed at the end of the shift and another card is prepared for the remainder of the exception.

CHAPTER 3

METALS

The Opticalman will work with metals at various times while working on optical instruments. Thus he should be familiar with types of metals, the properties of metals, and the heat treating processes for the most common metals.

There is no simple definition of metal. All chemical elements that possess metallic properties are classed as metals. The metallic properties might be defined as luster, good thermal and electrical conductivity, and the capability of being permanently shaped, or to some extent deformed, at room temperature. Other chemical elements, lacking these properties, are classed as nonmetals. Some elements—carbon, phosphorus, silicon, and sulfur, for example—behave sometimes like metals, sometimes like nonmetals, and are known as metalloids. An alloy is defined as a substance having metallic properties, that is composed of two or more elements.

PROPERTIES OF METALS

Metals and alloys vary widely in their characteristics or properties. Chemical properties involve the behavior of the metal in contact with the atmosphere, salt water, or other environments. Physical properties relate to color, density and weight, magnetic qualities, electrical conductivity or resistance, and heat conductivity. Mechanical properties relate to load carrying ability, wear resistance, and elasticity.

The various properties of metals and alloys have been determined in the laboratories of manufacturers and are tabulated and indexed by various engineering societies interested in metallurgical development. Charts which give properties pertaining to a particular metal or alloy are published in such reference books as the Metals Handbook. The charts provide information on the physical and mechanical properties which have been determined.

What are the properties which an Opticalman needs to understand about the metals most commonly used? They include the mechanical properties of hardness, toughness, tensile strength, ductility, and malleability. Following is an explanation of the meaning of these terms.

The HARDNESS of a metal is that property which enables it to resist scratching, denting, cutting, or erosion. It may also be defined as the ability of the metal to resist penetration. A piece of lead, for example, can easily be scratched with a knife. But it would be difficult to mark a piece of steel in this manner. The reason is that steel possesses the property of hardness, and thus provides resistance to scratching and cutting.

TOUGHNESS is that property of a metal which enables it to withstand shock loading without breaking.

It is thus related to strength and to ductility. Usually, the hardness of a metal increases as the toughness decreases.

TENSILE STRENGTH is that property of a metal which resists forces that would tend to pull the metal apart. It is measured in terms of pounds per square inch which represents the load that must be exerted on a cross-sectional area in order to break the metal.

DUCTILITY is that property that renders a metal capable of being drawn into wire form, stamped, or hammered into sheets. In other words, when the metal is placed under a severe load, it deforms rather than fractures.

MALLEABILITY is the property of metal that permits it to be rolled, forged, hammered, or drawn, without cracking or breaking.

CORROSION RESISTANCE though not a mechanical property is also of primary importance. Corrosion resistance is the property that enables a metal to withstand chemical or electrochemical attack by air, moisture, soil, or other agents.

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The various mechanical properties described may at times be desirable, and at other times be undesirable, depending on the purpose for which the metal is to be used. But resistance to corrosion is always a highly desirable characteristic.

TYPES OF METALS

The metals with which you work can be divided into two general classifications, ferrous and nonferrous. FERROUS metals are those that are composed primarily of iron. NONFERROUS metals are those that are composed primarily of some element or elements other than iron. Nonferrous metals or alloys sometimes contain a small amount of iron as an alloying element or as an impurity.

FERROUS METALS

A few examples of ferrous metals include pig iron, cast iron, ingot iron, and wrought iron. Carbon steel and the various alloy steels—structural as well as tool steel—are also considered as ferrous metals, since they are composed of iron to which relatively small percentages of carbon and other elements have been added as alloys.

Pig iron is composed of about 93 percent iron, from 3 to 5 percent carbon, and varying amounts of other elements. It is comparatively weak and brittle, and has a limited use.

The term cast iron may be applied to any iron in which the carbon alloy is more than 1.7 percent. Cast iron has high compressive strength and good wear resistance, but it lacks ductility, malleability, and impact strength.

Wrought iron is made from pig iron by a process of puddling, squeezing, and rolling. This process removes many of the impurities, and gives the wrought iron a type of fibrous internal structure which promotes workability.

Ingot iron is a commercially pure iron (99.85 percent), easily formed and possessing good ductility.

Of all the different metals and materials which you will use while in the Navy, by far the most important is steel. Steel is manufactured from pig iron by decreasing the amount of carbon and other impurities present. About 15 pounds of manganese, an indispensable addition in the production of steel, is added to each ton of pig iron.

Most of the steel you use will be in the form of structural shapes, such as sheet, plate, and bar. The types of structural steel are: mild steel, medium steel, high tensile steel, special treated steel, and stainless steel.

Mild steel is used when structural strength is of no great importance, and when a great deal of flanging, shaping, and other shop operations are involved.

Medium steel is similar to mild steel in its workability. But, it is harder and stronger than mild steel and is used when structural strength is required.

High tensile steel, usually referred to as RTS, contains small additions of various alloys that give the steel extra hardness and toughness.

Special treated steel, known as STS, contains a small percentage of chromium-nickel; and the product has been specially treated to obtain hardness and toughness.

Stainless steel, referred to as SST, is generally designated by the percent of chromium and nickel; for example, an 18-8 stainless is an alloy containing 18 percent chromium and 8 percent nickel.

NONFERROUS METALS

As an Opticalman you may work with various types of nonferrous metals. Some of the major types and their uses are discussed in this section.

Copper and copper alloys rank high among commercial metals with respect to desirable properties. Copper is ductile, malleable, hard, tough, strong, wear resistant, machinable, and weldable. Also it has high tensile strength, fatigue strength, and thermal and electrical conductivity. Copper is easy to work, and although it becomes hard when worked, it can easily be softened (annealed) by heating it to a cherry red and then letting it cool. Annealing is the only heat treating procedure that is applied to copper.

Lead is a heavy metal, weighing about 710 pounds per cubic foot. Yet lead is soft and malleable. It is available in pig and sheet form; sheet lead is rolled up on a rod so that the user can unroll and cut off the amount required. The surface of lead is grayish in color, but scraping the surface will show that the color of the metal is actually white. Because of its softness, lead can be used in various jobs. Sheet lead is used for bench tops where a great deal of acid is used. Lead lined pipe is used for systems that must carry chemicals. Alloyed with tin, in various proportions, it produces a soft solder.

Lead is often added to metal alloys to improve machinability. In working with lead, remember that its dust, fumes, or vapor can be highly poisonous.

Zinc is used often as a protective coating, known as galvanizing, on steel and iron. Zinc is also used in soldering fluxes, in die castings, and as an alloying element in making brass and some bronze.

Tin has many important uses as an alloying element. Remember that it can be alloyed with lead to produce soft solders; and alloyed with copper, it produces bronze. Tin base alloys have a high resistance to corrosion; they also have a low fatigue strength, and a compressive strength which will accommodate light or medium, but not heavy, loads.

Tin, like lead, possesses a good resistance to corrosion; it has the added advantage of being nonpoisonous. But when subjected to extremely low temperatures, it has a tendency to decompose. Aluminum is easy to work and has a good appearance. Although light in weight, it has a high strength per unit weight, but its tensile strength is only 1/3 that of iron, and 1/5 that of annealed mild steel. In its pure state, aluminum is soft, and has a strong affinity for gases. The use of alloying elements overcomes these disadvantages.

True brass is an alloy of copper and zinc. Additional elements—aluminum, lead, tin, iron, manganese, or phosphorus—may be added to give the alloy specific properties.

Bronze made of 84 percent copper and 16 percent tin was the best metal available before steelmaking techniques were developed. Many complex bronze alloys, containing additional elements such as zinc, lead, iron, aluminum, silicon, and phosphorus, are now available.

Monel is an alloy in which nickel is the predominate element. It contains from 64 to 68 percent nickel, about 30 percent copper, and small percentages of iron, manganese, and cobalt. It is harder and stronger than either nickel or copper, and has high ductility. It has many of the qualities of stainless steel, which it resembles in appearance, and its strength and high resistance to atmospheric corrosion make it an acceptable substitute for steel in a system or service where atmospheric corrosion resistance is of primary importance.

HEAT TREATING PROCESSES

Metals in a solid state can be heated and cooled to change or improve a physical or mechanical property or a combination of properties. A metal part is heat treated in order to make it softer, more ductile, stronger, harder, or more resistant to wear. These properties are developed as needed to improve the usefulness and safety of a part for a definite purpose. No one heat treating operation can produce all these characteristics, and the improvement of some properties must be accomplished at the expense of other properties.

There are different forms of heat treating. Common forms used by the Navy include: annealing, normalizing, hardening, tempering, and stress relieving. The particular process used is determined not only by the physical properties to be developed or modified, but also by the composition of the metal. Ferrous metals may be hardened, tempered, annealed, and normalized. Most nonferrous metals can be annealed, and many can be hardened, but they are never tempered or normalized. (For nonferrous metals, the hardening process is usually referred to simply as heat treatment.)

While all heat treating processes are similar in that they involve heating and cooling, they differ in the temperatures to which the metals are heated, the rate of cooling, and the cooling medium. In addition, some of these processes not only effect changes in physical properties, but also alter the surface composition of the metal.

For all metals, time and temperature are the important factors in the heat treating operation. Usually, the atmosphere surrounding the metal during heating, or during heating and cooling, is also critical.

ANNEALING

Two main purposes of annealing are (1) to relieve internal strains, and (2) to make a metal soft enough for machining. Practically all metals, ferrous and nonferrous, may be annealed, and no elaborate equipment is essential. It is possible to produce good anneals by using a heating torch or a furnace. The basic process consists of heating the metal to a specified temperature, holding it at that temperature for a specified length of time, and then cooling it slowly to room temperature. Both the temperature of the operation and the rate of cooling depend upon the metal being treated, and the purpose for which it is to be used.

Annealing temperature for any metal should be slightly above the recrystallization point of the metal. Cast iron ordinarily must be heated to a point between 1400° and 1500° F. Pure aluminum can be annealed at temperatures from 625° to 700° F, but aluminum alloys require somewhat higher temperatures, depending upon their composition. Pure copper can be annealed at temperatures from 800° to 1200° F; most brasses (copper-zinc alloys) require annealing temperatures of from 475° to 650° F. Nickel-chromium alloys, which can withstand extremely high temperatures without appreciable damage, must be heated to annealing temperatures between 1800° and 1950° F.

Soaking or hold time depends upon the mass and the composition of the metal. Also, the rate at which a metal is cooled back to room temperature depends upon the composition of the metal. Alloys whose constituents precipitate on slow cooling from the solid solution temperature are of the age hardening type. Precipitation itself is a form of age hardening treatment; if the hardening constituent; if the hardening constituent of an alloy is in excess of the amount soluble at room temperature, the excess amount will precipitate, causing an increase in hardness and strength.

Rapid cooling suppresses precipitation, and the alloy remains soft at room temperature. For metals whose constituents precipitate after or during fast cooling, it may be necessary to furnace-cool the metal in order to produce complete softening.

Cooling methods also differ according to the type of metal concerned. Pure aluminum can be cooled in air; pure copper can be cooled in air, or quenched in water. Steel must be furnace-cooled, and the cooling rate must be kept slow, to produce maximum softness.

In annealing, avoid overheating the metal being treated. Overheating will cause increased grain size. There is also danger of burning the metal and, in ferrous metals, decarburizing the surface if a protective atmosphere is not provided.

NORMALIZING

Normalizing is a heat treating process similar to annealing, but it is applied to ferrous metals only. The purpose of normalizing is to refine internal grain structure, and to relieve stresses and strains caused by welding, forging, uneven cooling of castings, machining, and bending. Where steel is to be hardened, it is advisable that it be normalized first; low carbon steels generally do not require normalizing, but giving them a normalizing treatment will cause no harmful results.

The process of normalizing—like other heat treatment processes—consists of three steps: heating the metal to a specified temperature, soaking it (that is, holding it at this temperature), and cooling it. In normalizing, the specified temperatures are, for each metal, a point from 100° F to 150° F above the transformation range. The holding time depends upon the thickness of the metal, but must be long enough to allow for uniform heating throughout. The metal should be allowed to cool evenly to room temperature in still air.

HARDENING AND TEMPERING

The primary purposes of HARDENING operations are to harden metal and, at the same time, increase the tensile strength. In steel, however, the hardening process increases brittleness; and, the rapid cooling of the metal from the hardening temperature sets up severe internal stresses. To reduce brittleness, and to relieve internal stresses, steel must be tempered after it has been hardened. Although hardening and tempering are separate steps in the heat treatment of a tool steel, the value of each procedure depends upon the other.

The hardening treatment for most steels consists of heating to the correct temperature, soaking it the required length of time, and then rapidly cooling it in oil, water, or brine. A point to remember is that too rapid a cooling rate will increase the danger of cracking or warping. The addition of alloys permits a slower rate of cooling, and several steels (high-speed tool steels) may be cooled in air.

The temperature to which you must raise steel for hardening should be about 50° to 100° F above its upper critical point. This is to ensure that every point in it will have reached critical temperature and to allow for some slight loss of heat when the metal is transferred to the cooling medium. Remember that it is cooled rapidly by quenching in oil, fresh water, or brine. Quenching firmly fixes the structural changes which occurred during heating, and thus causes the metal to remain hard.

If allowed to cool too slowly, the metal will lose its hardness. On the other hand, to prevent too rapid quenching—which would result in warping and cracking—it is sometimes necessary to use oil instead of fresh water or salt water for high carbon and alloy steels. (Note: Salt water gives a faster quench but does not necessarily give a higher hardness. Hardness is dependent to an extent upon the quenching medium; however, an oil hardening steel will not be harder if quenched in brine.)

In cooling, you have to bring carbon steel to a temperature somewhat below 1,000° F in less than 1 second; and from this point downward, a rapid cooling rate must still be maintained. Alloys added to steel increase this 1-second limit for lowering the temperature; therefore, alloy steels can be hardened in a slower quenching medium.

Although all ferrous metals can be hardened by heat treatment, the degree to which they can be hardened varies considerably. For example, such ferrous metals as pure iron, wrought iron, and low-carbon steels contain very little hardening element (carbon), and this type of heat treatment will have little appreciable effect in hardening them. Cast iron can be hardened, but here, too, the effect is limited. If cooled too rapidly, cast iron forms a hard and brittle white iron; if cooled too slowly, it forms a gray iron that is soft and brittle under impact.

Some nonferrous metals and alloys can be hardened by cold working and rolling. These processes increase the strength of nickel alloys, copper, and wrought brass; some aluminum alloys and several copper base alloys are hardened by an aging process.

TEMPERING, also called DRAWING, is a process generally applied to steel to reduce brittleness and relieve stresses developed during the hardening process. Tempering always follows, never precedes, hardening. It differs from annealing, normalizing, and hardening in that the tempering temperatures are always BELOW the lower critical point. As it reduces brittleness, the tempering process also softens the steel. One property must be sacrificed to some extent in order that another property may be improved. High speed steel is an exception, since tempering high speed steel increases its hardness to a limited extent.

Tempering is accomplished by heating the hardened steel to a temperature below the critical range, holding this temperature for a sufficient time to penetrate the whole piece, and then cooling the piece in water, oil, or air. The tempering temperature for hardened steel is determined by the degree of hardness and toughness desired.

Tools with cutting edges are not tempered above 650° F; the hardness required for penetration is lost if a hardened steel is heated beyond this temperature. However, the toughness and shock resistance of the steel improves as it is reheated beyond 650° F. When reheats beyond 650° F are enployed, the operation is frequently called TOUGHENING. You will soon learn, by trial, the temperature at which a tool must be tempered. Table 3-1 gives the temperatures for tempering various plain carbon steel tools.

Table 3-1.—Temperatures for Tempering Various Plain Carbon Tools.

Degrees Fahrenheit	Tool
400°	Hammer faces, machine cutting tools
460°	Tape and dies
480°	Punches, reamers, dies, knives
500°	Twist drills
520°	Drift pins, punches
540°	Cold chisels
550°	Screwdrivers, springs

The following description of a common method used to harden and temper chisels will help to clarify the meaning of hardening and tempering. Bring 2 1/2 to 3 inches of the cutting edge of the tool up to hardening temperature. Then, using tongs to hold the chisel, quench by plunging 1 1/2 to 2 inches of the heated end into the quenching medium. Jiggle the tool rapidly, using an up-and-down, forward-and-backward motion; and, as you do so, make sure you keep the point immersed 1/2 inch in the quenching medium.

When the metal has cooled down to a black heat (900° to 950° F), remove the tool from the quench tank. Then quickly polish the tapered end with an emery board and watch the temper color "run out" until the desired color appears (usually peacock to dark blue). Then quench the entire tool.

It is well to remember that every chisel you see is not a water-hardened chisel. Many are manufactured from special alloys and are oil-hardened. Most chisels of this type have directions for treating stamped on the shank as follows: 1350 W 400 or 1600 O. The first means to heat to 1,350° F, quench in water and temper at 400° F. The second means to heat to 1,600°F, and quench in oil. It is not necessary to temper this tool, as it is a special alloy. Other alloy chisels will have different directions stamped on the shank. Generally, it is safe to assume that an unmarked chisel is a carbon steel water-hardened tool.

STRESS RELIEVING

Stress relieving is a heat treating process in which uniform heating is essential, but the temperature to which the part is raised is not as high as that required for annealing and normalizing. The purpose of stress relieving, as the name implies, is to relieve stresses developed in metals during mechanical working or solidification.

Stress relieving involves temperatures below the transformation point of ferrous metals. The main factors in stress relieving are the temperature of the treatment and the time the part is held at that temperature. Stress relief becomes more effective as the temperature is increased. For example, with gray cast iron, the percentage of stress relief at temperatures below 750° F is negligible. Above this temperature, the percentage of residual stress relieved increases rapidly with increase in temperature. However, if the temperature closely approaches the transformation range, structural changes will begin to occur. As a rule, when stress relieving is applied, structural changes are not desirable. Consequently, the temperature selected should give the greatest possible stress relief with the least possible change of properties. For gray cast iron, the stress relief temperature is 950° F. At this temperature from 60 to 90 percent of the original internal stress is relieved and a minimum of structural change occurs.

Stress relieving is accomplished by heating the metal slowly and uniformly to a predetermined temperature. The rate of heating should not be less than 400° F per hour for most metals. When the metal attains the desired temperature, hold or soak at this temperature no less than 1 hour for each inch of thickness of the thickest section. Then allow the part to cool very slowly to room temperature. The cooling rate should not exceed 200° F per hour for any metal. Since the majority of stress relief occurs during the first hour after the part attains the proper temperature, it is essential that hold time be counted from the time the metal, not the furnace, reaches the stress relieving temperature. Remember, slow cooling is essential. If the part is cooled rapidly, new internal stresses develop, defeating the purpose of the treatment.

In steel, stress relieving is often the final heat treatment. Here the stress relieving temperature is at least 50°F, but not more than 100° F, below that of the preceding heat treating temperature. A temperature of 750° relieves about 50 percent of the stress in a steel casting, while a temperature of 1,000° F relieves more than 90 percent. Typical practices for stress relieving common metals are presented in table 3-2.

Table 3-2.—Stress Relieving Data

Material	Temperature (° F)	Hold time (hours per inch thickness)
Gray cast iron . . .	950	1
Low carbon steel .	1,150	1
Carbon-molybdenum steel	1,250	2
Chrominum-molybdenum steel . . .		
(0.5 Cr-0.5 Mo).	1,250	2
(2 Cr-0.5 Mo) . .	1,325	2
(9 Cr-1 Mo) . . .	1,400	3
Copper	300	1/2
Brass:		
(70 Cu-30 Zn) . .	500	1
(60 Cu-40 Zn) . .	375	1/2
Bronze (90 Cu-10 Sn)	375	1
Stainless steel . . .	1,550	2
Monel	550	2

CHAPTER 4

PHENOMENA OF LIGHT

There are many strange phenomena about light, some of which you studied in Opticalman 3 & 2, NavPers 10205. It would be to your advantage to go back and review the chapter on characteristics of light which will help you to have a better understanding of the information on light in this chapter. Information on interference, polarization, and double refraction follows.

INTERFERENCE OF LIGHT WAVES

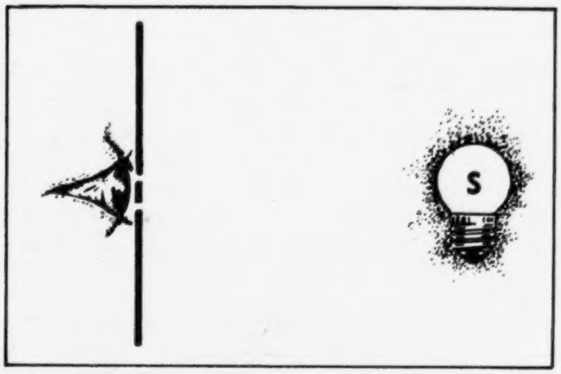
The wave nature of light has been substantiated by various studies of light interference. These studies have also produced other interesting light facts. Interference in light waves gives us a direct and accurate means for measuring wavelengths. Credence to Einstein's theory of relativity, on the other hand, was provided by unsuccessful endeavors to measure variations in light velocity by the interference methods. Einstein contended that the velocity of light is constant and unaffected by the motions of an observer.

The first man to become interested in the effects of interference was Thomas Young, in 1801. He had the idea that if light were a form of wave motion it must act the same way water would, if subjected to the proper conditions. Since water can show the effects of interference, he felt sure he could produce the same effects with light. To show he was right, he took two similar trains of water waves. He said that if the elevations of one wave coincide with the elevation of the other wave, they must together produce a greater wave; but, on the other hand, if the elevation of one wave coincides with the depression of the other wave and fills up that depression, the waves cancel each other out. From this we get the two phases of interference, constructive and destructive.

Young's theory shows he had come to believe in Huygens' wave theory of light; his theory was opposed to Newton's corpuscular theory.

YOUNG'S EXPERIMENT

Young went further into the theory of interference to prove he was right by conducting an experiment. He took a piece of black paper and put two narrow slits in it, as in figure 4-1, about 1 mm apart. Behind the black paper he placed a source of light 3 or 4 meters away. When he looked through the slits at the source of light, he could see a series of dark and light bands, as shown in figure 4-2. When he put a red filter between the light source and the slits, the series of dark and light bands became red and black.



148.1
Figure 4-1.—Double-slit interference.

Figure 4-3 shows the same double-slit interference, but this time we use a monochromatic light source(s). (A monochromatic light source is a single wavelength of a very small range of wavelengths). Slits X_1 and X_2 are parallel to the source and both must be the same distance from it. When light from the source reaches the slits, the slits can then be considered new light sources

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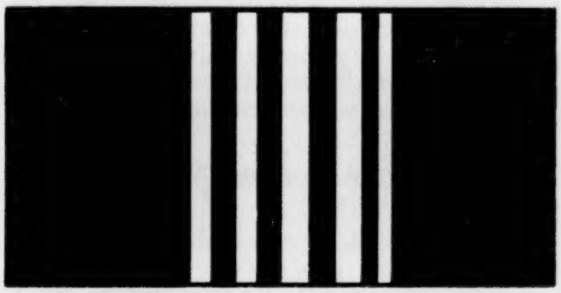
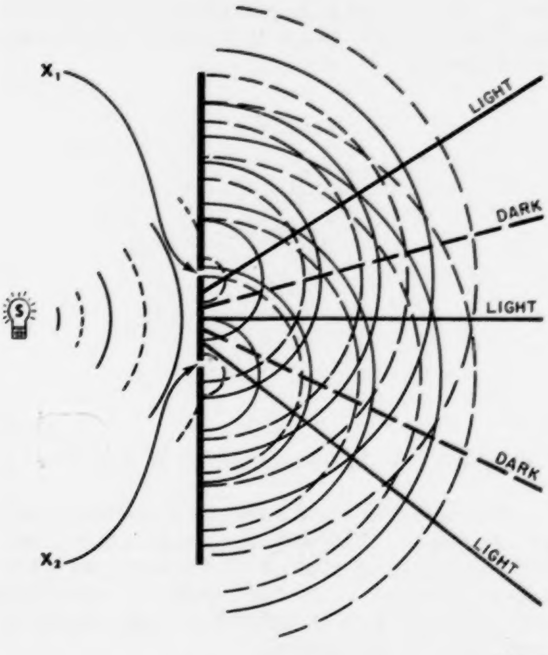


148.2
Figure 4-2.—Fringes from double-slit interference.



148.3
Figure 4-3.—Double-slit interference wave-front diagram.

because they are producing new wave fronts. As the new wave fronts become larger, part of the waves produce constructive interference and make bright bands of reinforced light. While this is happening, the other wave fronts produce destructive interference and make the dark bands of light. These bands of light are hard to see, unless you use a screen of some type to project them on.

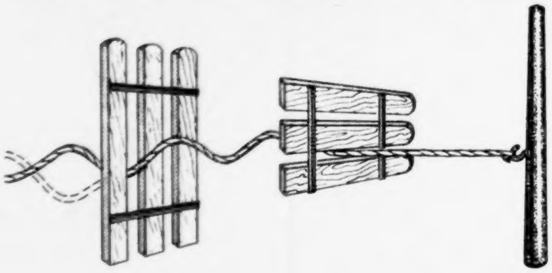
FRESNEL'S EXPERIMENT

The criticism of Young's experiments made Augustin Fresnel feel he should prove Young's experiments were right. Many who saw Young's experiments were still unconvinced. They thought that the spreading of light as it passed through the slit was not due to wave motion but to reflections from the flat edges of the slit. To prove this was not true, Fresnel constructed a device which used the sharp edges of two razors for the edges of his slit. Then he constructed another exactly the same width, but this time he used the flat and polished backs of two razors. When the experiment was completed, he proved that it made no difference about the edges of the slits. With this experiment, and others, Fresnel helped to make the wave theory become generally accepted.

POLARIZATION

The first man to know the meaning of polarization was Fresnel. He knew that transverse waves vibrate at right angles to the direction of propagation (spreading of light). At the same time, he also knew that transverse waves could be polarized and that longitudinal waves could not be polarized. Huygens could not explain polarization because he thought light consisted of longitudinal waves.

The following example illustrates the theory of polarization. Suppose that a rope is passed through two slats of a picket fence: if the rope is vibrated parallel with the slats, transverse waves would be able to pass through; but if the rope is vibrated at right angles to the slats, the waves would not be able to pass through, as illustrated in figure 4-4. Polaroid films and tourmaline act in the same way as the slats in the fence, except that they act on light waves. By using two polaroid films, you can cancel out



148.4
Figure 4-4.—Mechanical similarity of polarization.

the light completely. The first film will let some of the light pass and the second film, if turned 90° to the first, will eliminate all remaining light.

This type of polarization is used on some optical instruments today. With a filter of this type, the amount of light through the filters can be adjusted by rotating one of the polaroid films. This is helpful, inasmuch as the Navy does not have to use two filters, such as one dark and one light. We can adjust a polaroid filter so that we have either light or dark. This is the principal of the variable density filter, which actually consists of two polarizing filters one of which is rotatable.

When you look through one polaroid film, you see what is called plane polarized light; that is, you see vibrations parallel to one plane. Ordinary light, as we see it every day, is unpolarized light, because it consists of many waves vibrating in different directions.

One method of producing polarized light, and the simplest, was discovered by Sir David Brewster in 1808. His method involved usage of the reflecting surface of glass. He discovered that if light were reflected at a particular angle the reflected light would be plane polarized. Brewster's law stated that maximum polarization of light by reflection is obtained when the reflected and refracted rays are at right angles (fig. 4-5).

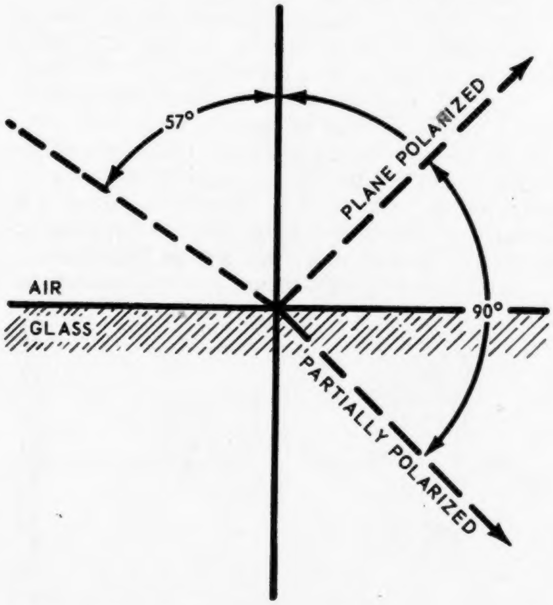
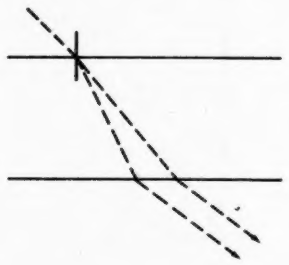


Figure 4-5.—Maximum polarization according to Brewster's law. 148.5

Another method of producing polarized light is when sunlight is scattered by the earth's atmosphere and is partially polarized. Because sunlight is partially polarized we have to use polarized filters on our cameras.

DOUBLE REFRACTION

There are some transparent crystals that can produce a double image. One of these crystals is called calcite (sometimes called Iceland spar). The double image is produced when each ray of light is split into two rays by the crystal and the two rays are bent or refracted through different angles (fig. 4-6). We know then that since the two rays are bent different amounts the indices of refraction in calcite must be different. This double image is what we call double refraction.



148.6
Figure 4-6.—Double refraction in a medium.

We know that some crystals do not have equal properties in all directions. If unpolarized light falls on a crystal such as calcite in any direction except parallel to the optic axis, the vibrations will occur in two directions at right angles to each other in the crystal.

The two rays that are split are called the ordinary ray and the extraordinary ray. Since the velocities of the two rays are different, the indices of refraction must also be different. One of these rays (ordinary ray), in which the index of refraction is constant and independent of the angle of incidence, is like ordinary refraction with glass. For the extraordinary ray, the index of refraction varies with the angle of incidence.

You do not always get double refraction from a crystal such as calcite, because there is one particular direction where there is no double refraction. When you do not get double refraction, both rays are traveling with the same velocity and the index of refraction is the same for both. This particular direction is the optic axis of the crystal. The optic axis is not a single line but the direction of all such lines which are parallel.

CHAPTER 5

RANGEFINDER THEORY AND CONSTRUCTION

Unless you are firing pointblank at your target, you must elevate the gun above your line of sight (LOS) in order to secure a hit. The exact angle of gun elevation depends chiefly on the range. Successful gunnery requires, then, that you have some means for measuring the distance from gun to target, quickly and accurately, without leaving your own ship. Optical rangefinders are used for this purpose and you will be working on them from time to time.

RANGEFINDER THEORY

You have seen a rangefinder, perhaps many times. Rangefinders are constructed in various lengths and diameters. Mounted at each end of the cylinder are end windows that allow the passage of light into the instrument, with eyepieces located in the center of the tube. The operator looks into the eyepieces, turns a knob, and reads on a scale the distance between his ship and some object several thousand yards away. To someone with no knowledge of optics, that might seem a little mysterious. But you should already have a good knowledge of the basic theory of the rangefinder.

Rangefinders are as old as the human race. Your two eyes serve as a very effective rangefinder at short distances. Your two pupils correspond to the end windows of an optical rangefinder, and your interpupillary distance corresponds to its base length. When you change fixation from one object to another at a different distance, you automatically change the angle at which your two lines of sight converge. By subconsciously noting that change of convergence angle, you come up with an accurate estimate of relative distances. (Assuming, of course, that both objects are within range of your steroscopic vision.)

Here is something you need not remember, but it may be of passing interest. Predatory animals, such as lions, bears, wolves, and people, have their eyes in the front of their heads. Because their two fields of view overlap, they have depth perception, and can estimate relative distances. Hunted animals, such as rabbits, have their eyes far around toward the sides of their heads. That gives them a wide field of view, so they can spot an enemy approaching from almost any direction. But the overlap of the two visual fields is slight, and they have little or no depth perception.

Rangefinding with the help of instruments is more recent. It started in the Nile valley, about 4,000 years ago. This was fertile valley, so that agriculture was highly profitable. But every spring the Nile river flooded, and washed away all the fences and boundary markers. The Egyptians had to develop a system of GEOMETRY (literally: earth-measure) to find out whose field was where.

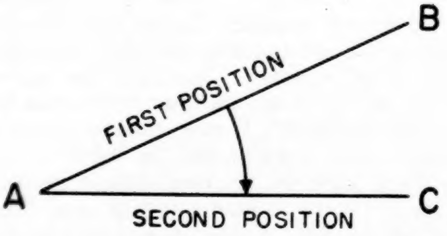
Practical geometry is based largely on the measurement of lines and angles. Let us review some of the more basic principles.

ANGULAR MEASURE

Everybody knows what an angle is; still it is not easy to readily define the term. An angle may be defined as a measure of the amount of turning necessary to bring one line or plane into coincidence with or parallel to another, as in figure 5-1. Here, we start with the line AB, then pivot this line at point A, and swing it around to position AC. The line, in rotating from its first position to its second, has generated the angle BAC.

THE DEGREE

To measure any quantity we must use UNITS, which are defined in terms of some arbitrary standard. (A unit is any determinate amount



148.7

Figure 5-1.—Angular measurement.

(as of length, time, heat, value)) adopted as a standard of measurement. The fundamental unit of angular measure is the DEGREE. We can best define it in terms of rotation. Imagine a circle, with one radius drawn in. Let us pivot that radius at the center of the circle and turn it through one complete revolution, back to its original position. That radius, in making one complete revolution, has generated an angle of 360°. Or we can look at it another way. We can divide the circumference of our circle into 360 equal parts, and mark off the divisions. A radius, in rotating from one mark to the next, will generate an angle of one degree.

A degree is a fairly small unit—each of those 360 angles in the circle is one degree. But with the help of optical instruments, we can measure even smaller angles, or measure large angles more precisely. To make convenient smaller units, we can divide each degree into 60 MINUTES, and each minute into 60 SECONDS. Then our system of angular measurement shapes up like this:

360 degrees equal one complete circle
60 minutes equal one degree
60 seconds equal one minute

The second is our smallest independent unit of angular measure; to measure more precisely than by seconds, you will have to use decimal fractions of a second.

CIRCULAR MEASURE

Circular measure is the measure of an angle with its vertex at the center of a circle—in other words, the angle formed by two radii. In circular measurement, we define an angle in terms of the relationship between the length of the radius and the length of arc intercepted by the two radii. The unit of circular measure used in conjunction with the rangefinder is the RADIAN. For some purposes, as you will see later, the radian is a more convenient unit than the degree.

THE RADIAN

In figure 5-2, the angle between the two radii is one radian. Consider first the radius OA; measure its length, r. Now, starting at point A, lay off on the circumference of the circle an arc whose length is equal to r, and mark point B at the end of it. Draw the radius OB. Then the angle between the two radii—the angle AOB—is one radian. The two arms of this angle intercept an arc whose length is equal to the radius of the circle.

There are as many radians in a circle as there are radii in its circumference. The circumference of a circle is equal to π times its diameter. [In geometry π (the Greek letter Pi) represents a constant; 3.14159+.] Since the diameter is twice the radius, the radius will go into the circumference 2 π times. So, there are 2 π radians in a circle.

How many degrees in a radian? Since there are 360° in a circle, there are $\frac{360}{2\pi}$ degrees (or 57.2956°) in a radian. (This and all other equivalents based on the value of π are only approximate, since π is an indeterminate number—an endless decimal.) Reducing 57.2956° to degrees, minutes, and seconds, we get:

1 radian equals 57°17'44.8''

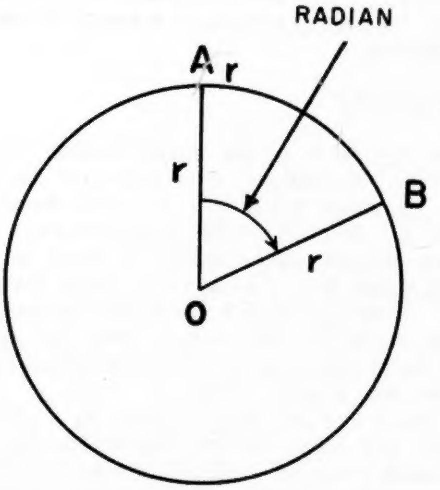
To make that figure easier to handle, we can convert it into seconds. Then we have:

1 radian equals 206,265 seconds

TRIANGULATION

What does all this geometry have to do with rangefinding? We will show you. The ancient farmers in the Nile valley discovered that when you have to measure a distance that you cannot reach directly, you can use the principle of triangulation. We use that principle in rangefinding. Modern surveyors still use the principle of triangulation to measure distances they cannot get at directly. Astronomers use it to measure the distance of the sun and planets, and some of the nearer stars.

Figure 5-3 illustrates the principle of triangulation, and shows the fundamental triangle of a rangefinder. You are at point A; another ship is at P; you want to measure her range without leaving your own ship. A surveyor would do it by laying off a line AB, of convenient

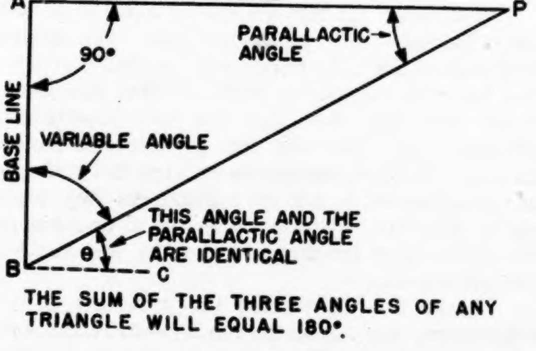


148.8
Figure 5-2.—Radian measurement.

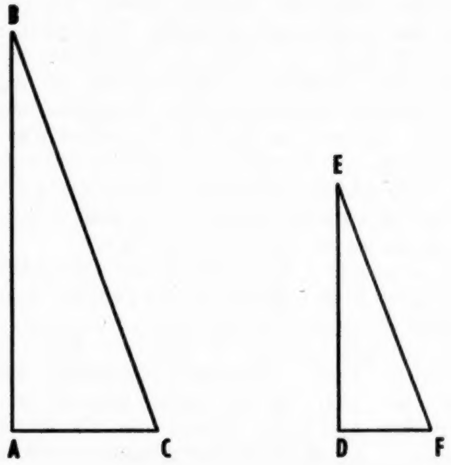
length, at a right angle to the line of sight AP. He would measure this line AB, as accurately as possible, with his tape measure. Then he would set up his transit at point B, and use it to measure the angle ABP. He would then have all the data necessary to calculate the range AP.

You should have a good knowledge of the principle of triangulation, but we will run through it just for review. It's all based on the principle of similar triangles. (Two triangles are similar when the three angles of one triangle are equal respectively, to the three angles of the other.) The two triangles in figure 5-4 are similar. In any pair of similar triangles, the relationship between corresponding parts is constant. Measure the lines AB and BC (in fig. 5-4), and then divide the length AB by the length BC; if your measurements are accurate, your answer will be 0.9397. Do the same thing with the corresponding parts of the smaller triangle; measure DE and EF, and divide DE by EF. Your answer will be 0.9397 again.

If you divide AC by BC you will get 0.3420. You can do the same thing with corresponding parts of the smaller triangle, or of any triangle similar to these two; the answer will always be the same.


A
RANGE
P
90°
PARALLACTIC ANGLE
BASE LINE
VARIABLE ANGLE
THIS ANGLE AND THE PARALLACTIC ANGLE ARE IDENTICAL
θ
B
C
THE SUM OF THE THREE ANGLES OF ANY TRIANGLE WILL EQUAL 180°.

148.9
Figure 5-3.—The fundamental triangle of a rangefinder.



148.10
Figure 5-4.—Similar triangles.

Remember that this will only hold true with any triangle that has an angle of 90°.

Look back at figure 5-3. Now, it is obvious how we can solve that whole triangle, and calculate the range AP, by measuring only those parts of the triangle that are on your own ship. How? By comparing APB with some similar triangle we are already familiar with. We know that angle A is a right angle, and we measured angle B using a surveyor's transit. We can easily calculate angle P, because we know that in any triangle the sum of the angles is equal to 180°. Now, if you wanted to, you could draw a small triangle similar to ABP, measure its sides, and calculate the ratio of the various parts. You would know that the corresponding parts of ABP would have the same ratio.

But we do not need to go to all that trouble. Mathematicians have calculated all these ratios for us, and listed them in table of trigonometric functions.

How can we calculate the range from the facts we know about the triangle in figure 5-3? We can do it by setting up an equation that contains the term we want to know (AP, the range) and other terms that we already know. What do we already know? We know the length of the side AB, and the value of all three angles.

We know that, in a right triangle, the side opposite one of the acute angles, divided by the side adjacent to that angle, is the tangent of that angle. We can apply that formula to the triangle in figure 5-3:

$$\tan\angle P = \frac{AB}{AP}$$

So we have an equation that combines our unknown (the range, AP) and other quantities that we know. If we solve it for the range, AP, we get:

$$AP = \frac{AB}{\tan\angle P}$$

We know AB, by measurement, and we know angle P; we can look up tan P in a table of trigonometric functions, and solve the triangle.

So, using the method of a surveyor, with his transit and tape measure, you can calculate the range of a target without leaving your own ship. But you can do it much more quickly with a rangefinder.

In figure 5-3, the points A and B correspond to the two end windows of your rangefinder; the line AB corresponds to the base of the rangefinder and is always constant for that particular rangefinder. We cannot measure the PARALLACTIC ANGLE (angle P) directly, because its vertex is aboard the other ship. But if we construct an imaginary line BC parallel to AP, then angle θ (Theta) will be identical with the parallactic angle, and can be easily measured.

The rangefinder can give us all the information we need to solve the triangle and calculate the range.

Using the triangulation formula

$$\tan\angle P = \frac{AB}{AP}$$

P is the parallactic angle, and since we are going to measure the identical angle θ, we can substitute tan θ for tan ∠ P. AB corresponds to the base of our rangefinder; let B represent the base in yards, and R the range AP in yards. Now our formula is:

$$\tan\theta = \frac{B}{R}$$

After a little thought you can see that the range will always be large when compared with the base of the rangefinder, and therefore the angle θ will always be very small. Now this may be surprising, but it is true: for very small angles, the tangent of the angle is almost exactly equal to the angle itself, WHEN WE EXPRESS THE ANGLE IN RADIANS. So, if we express θ in radians, then:

$$\theta = \frac{B}{R}$$

There you have the RANGEFINDER FORMULA.

But suppose we want to express θ in seconds, rather than radians. We know that there are 206,265 seconds in one radian. Therefore, if we express θ in seconds:

$$\theta = 206{,}265\ \frac{B}{R}\ \text{seconds}$$

From that formula, we can calculate the value of the parallactic angle, θ, for any given rangefinder at any given range. But the job of the rangefinder itself, of course, is to measure θ, and convert it into yards of range for us.

Let us go back for a minute to your personal rangefinder—your own two eyes. How does it work? Though you probably do not realize it at the time, you estimate the relative distance of two objects by comparing their parallactic angles. Since a nearby object has a greater parallactic angle than a distant one, you know that the object with the greater parallactic angle is closer than the other.

Of course there is a limit to the usefulness of your personal rangefinder, because there is a limit to your STEREO-ACUITY. To the average trained observer, two parallactic angles will appear to be equal unless the difference between them is 12 seconds or more. Since the base of your personal rangefinder is short (65 mm is average), its effectiveness is limited to comparatively short ranges.

How can we extend that range? Let's consider two distant objects, whose parallactic angles are 1 second and 2 seconds, respectively. To the naked eyes, of course, they will appear to be at the same distance, because the difference in their parallactic angles is too small to detect. You cannot tell which of these objects is closer unless you find some way to increase the difference between their parallactic angles to 12 seconds or more.

Now suppose that you mount two 12X (12 power) telescopes side by side and parallel, with the centers of their eyepieces about 65 millimeters apart. You can look through one of these telescopes with one eye, and the other one with your other eye. The telescopes will magnify both objects 12 times, and thus increase their parallactic angles to 12 seconds and 24 seconds, respectively. The difference is now 12 seconds, and you can estimate the relative distance of the two objects.

You could also extend the range of your depth perception if it were possible to increase your interpupillary distance. You can easily see that, for an object at any given distance, increasing the base of the triangle will increase the parallactic angle.

The optical rangefinder uses both these means to extend the range of your depth perception. It provides you with a magnified image of the target. It provides you with two lines of sight through its two end windows, which are much farther apart than the pupils of your eyes. By using a rangefinder with a magnification of 24X, and a base length 100 times your interpupillary distance, you can increase your depth perception by a factor of 2,400.

OPTICAL CONSTRUCTION OF THE RANGEFINDER

You can easily understand the construction of a rangefinder if you compare it with other instruments you have already studied. In figure 5-5 you see two simple gunsight telescopes, laid out with all their elements in a straight line. The two eyepieces (doublets) face inward; the two objective lenses are at the ends of the line. Since you now have two lines of sight, through two separate telescopes, you have the essential elements of a rangefinder. But to make it useful, you will have to add a few features. Your two lines of sight are pointing in opposite directions; actually, you want them to converge on a single object. You can do that by adding two reflecting surfaces on the optical axis—one beyond each objective—to deflect the lines of sight forward. To make the incident rays enter your eyes, you must add two more reflecting surfaces to the axis, one near each eyepiece. Now you have the system shown in figure 5-6.

We have used a penta prism at each objective, to reflect rays from the target onto the optical axis. We have added two prisms (numbered 7) that reflect the rays to the observer's eyes. We now have a system that will increase your depth perception tremendously. It magnifies your target and effectively increases your interpupillary distance. By using this system you can easily estimate the relative distance of two objects, even at a great distance. But estimating relative distance is very different from measuring actual distance. To make this system into an effective rangefinder we will have to add a measuring device.

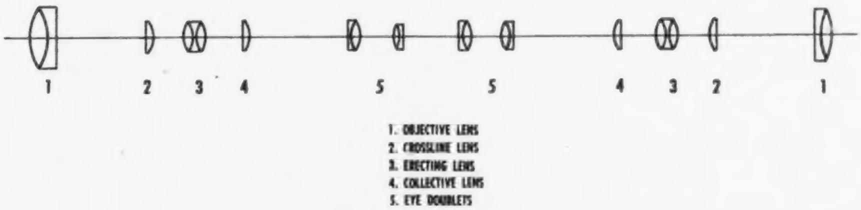
The two diagrams in figure 5-7 are schematic drawings of a coincidence rangefinder—the type with a single eyepiece. The cross at C represents a coincidence prism. It enables you to see through both telescope systems at once, with one eye; your field of view appears to be split by a horizontal line; the lower half of the image is formed by one of the telescopes, the upper half by the other.

Look at the upper diagram in figure 5-7. The rangefinder has been turned so that ray A from the target is at a right angle to the optical axis. After reflection in the left penta prism, L, ray A will coincide with the axis; it will strike the center of the coincidence prism at C, and will be reflected to the observer's eye at E.

If your target were at infinity, all rays from a given point on it would be parallel. The ray entering the right penta prism, R, would behave like ray B—it would be reflected along the axis, and after reflection at the coincidence prism it would coincide with ray A. To the observer, the two halves of the image would appear to coincide and form one unbroken image.

But actually your target will be at a definite distance. The broken line B' represents a ray from a target at a definite distance. It will strike the face of the right penta prism at a slight angle—the parallactic angle, θ. After reflection in the penta prism it will diverge from the axis at the angle θ, and after reflection in the coincidence prism it will fail to coincide with A. The observer will see a broken image of the target; half the image will be displaced to one side.

In the lower diagram (part B of fig. 5-7), we have inserted a pair of measuring wedges; think of them as a pair of thin prisms. A prism, of course will deviate a ray of light



148.11

Figure 5-5.—Telescopic system of a rangefinder.

toward its base. If we choose our prisms carefully, we can make them deviate the ray B' through angle θ. Then, after the ray passes through the measuring wedges, it will lie on the optical axis, and the observer will see an unbroken image of the target.

If necessary, we could actually measure ranges that way. We could select, by trial and error, one or more prisms that would make the image halves coincide. Then, if we knew the deviation of those prisms, we would know θ, and could calculate the range. But a system like that would be slow, and it would keep the operator pretty busy.

Actually, rangefinders use a simpler principle. The measuring wedges are so mounted that you can rotate them on the axis by turning a knob. The deviation will vary with the amount of rotation. By turning the ranging knob you can rotate the wedges until their deviation is equal to θ. We can mount a scale in this system, to indicate the amount of rotation. And, by suitable tests on targets at known distances, we can calibrate that scale to show the range in yards.

This is the basic principle of the rangefinder. There is more to it than that, of course, but the other elements are accessories. They help to make the instrument more accurate, and convenient to use, and provide an easy means of calibrating it.

TYPES OF RANGEFINDERS

The Navy uses two types of rangefinders: the COINCIDENCE type, and the STEREOSCOPIC type. The two instruments have many features in common; each consists of two telescopes, one in each half of the instrument. Both types measure the parallactic angle, and calculate the range from that measurement. The principal difference is in the way the target image is presented to the operator's eyes.

The COINCIDENCE RANGEFINDER has a single eyepiece. The operator's field of view is split by a horizontal line; the upper half is formed by one of the two telescopes, the lower half by the other. To operate the coincidence rangefinder, the operator turns the ranging knob—thus rotating the measuring wedges—until the two halves of the image coincide. He can then read the range, in yards, on the scale. When the rangefinder is not set to the proper range, the operator sees a broken target; half the image will be displaced to one side, as in figure 5-8.

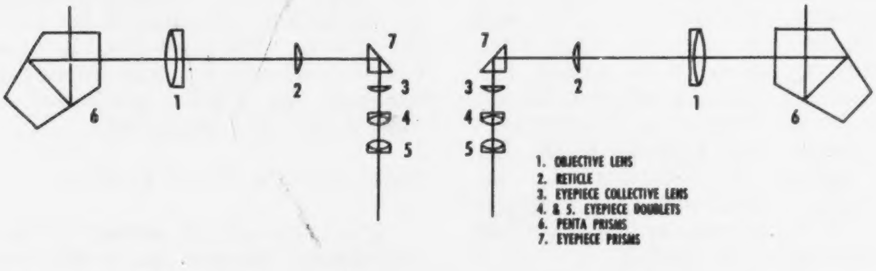


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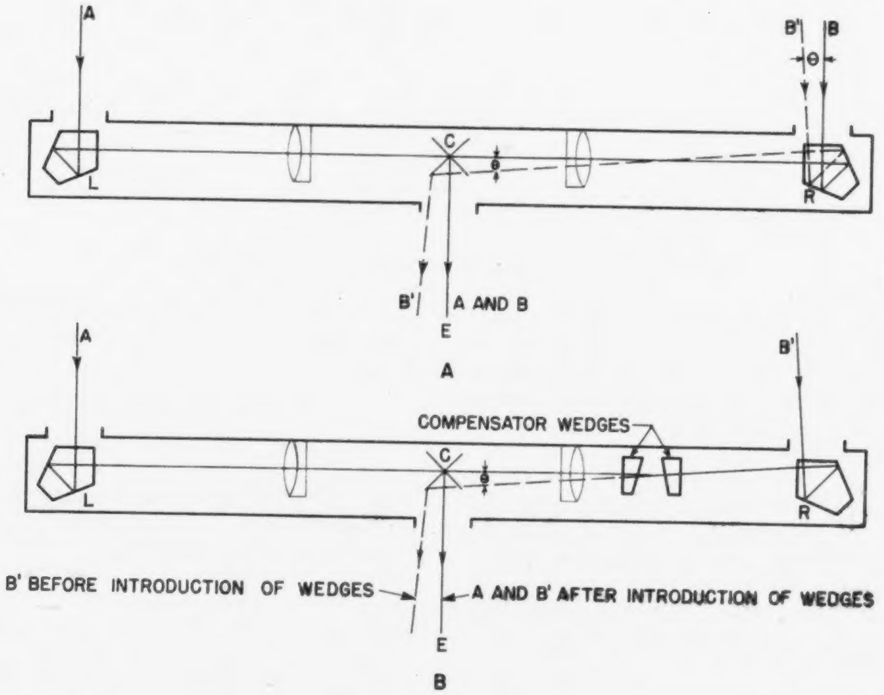
Figure 5-6.—Basic optical system of a rangefinder.


A
B'
B
θ
C
θ
L
R
B'
A AND B
E
A
A
B'
COMPENSATOR WEDGES
C
θ
L
R
B' BEFORE INTRODUCTION OF WEDGES
A AND B' AFTER INTRODUCTION OF WEDGES
E
B

148.13

Figure 5-7.—The rangefinder principle.

The STEREOSCOPIC RANGEFINDER has two eyepieces. In ranging with this instrument the operator makes use of his own stereo-acuity—his ability to estimate the relative distance of objects. When he looks through the eyepieces he will see a single, unbroken image of his target. Superimposed on that image he will see a pattern of reference marks. (This pattern is engraved on the reticles in the two telescopes of the rangefinder.) Figure 5-9 shows a typical reticle pattern for a stereoscopic rangefinder.

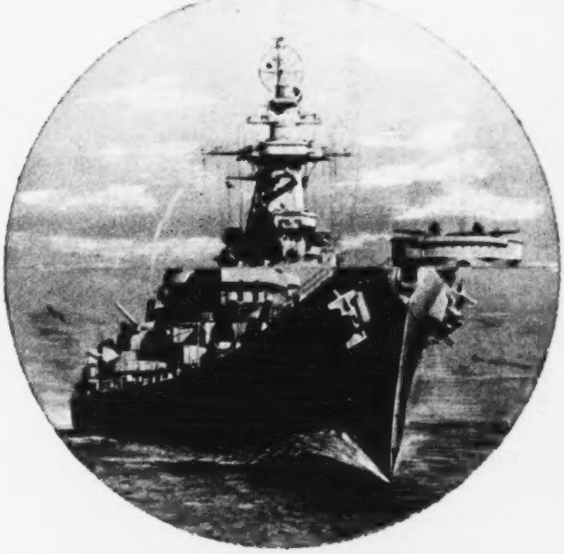
To the operator, this reticle pattern will appear to be spread out in space—some of the vertical marks will appear to be closer than the diamonds; others will appear to be farther away. (This is an illusion—or "artificial" stereoscopis effect. The patterns of the two reticles are similar but not identical. By viewing a separate reticle with each eye, you get an effect of stereopsis, and the pattern appears to be spread out in space.)

To the rangefinder operator, the center row of reference marks—the diamonds, in figure 5-9—may appear to be closer or farther away, than the target. By turning the ranging knob, and thus rotating the measuring wedges, the operator can make the target appear to move in either direction. When the target and the diamonds appear to be at the same distance, the rangefinder is properly set, and the operator can read the range on the scale.

In naval use, the stereoscopic rangefinder has largely replaced the coincidence type. If the operators are thoroughly trained, there is no significant difference in the accuracy of the two types. But when ranging on aircraft, or under conditions of poor visibility, a skilled operator can usually get better results with the stereoscopic rangefinder.

COINCIDENCE RANGEFINDER

The main optical system of the coincidence rangefinder includes these elements: end windows, end penta prisms or end reflectors, measuring wedges or compensator wedges,



148.14

Figure 5-8.—Field of view of the coincidence rangefinder.

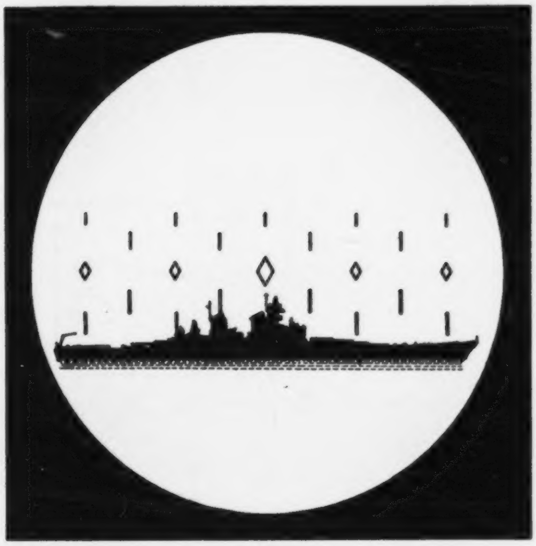


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Figure 5-9.—Field of view in a stereoscopic rangefinder.

correction wedge, main objective lenses or objective lens groups, coincidence prism, main eyepiece group, astigmatizers, and color filters. Some instruments also have change of magnification lenses. Figure 5-10 shows the optics of a typical coincidence rangefinder, Refer back to this illustration as we describe the principal elements.

End Windows

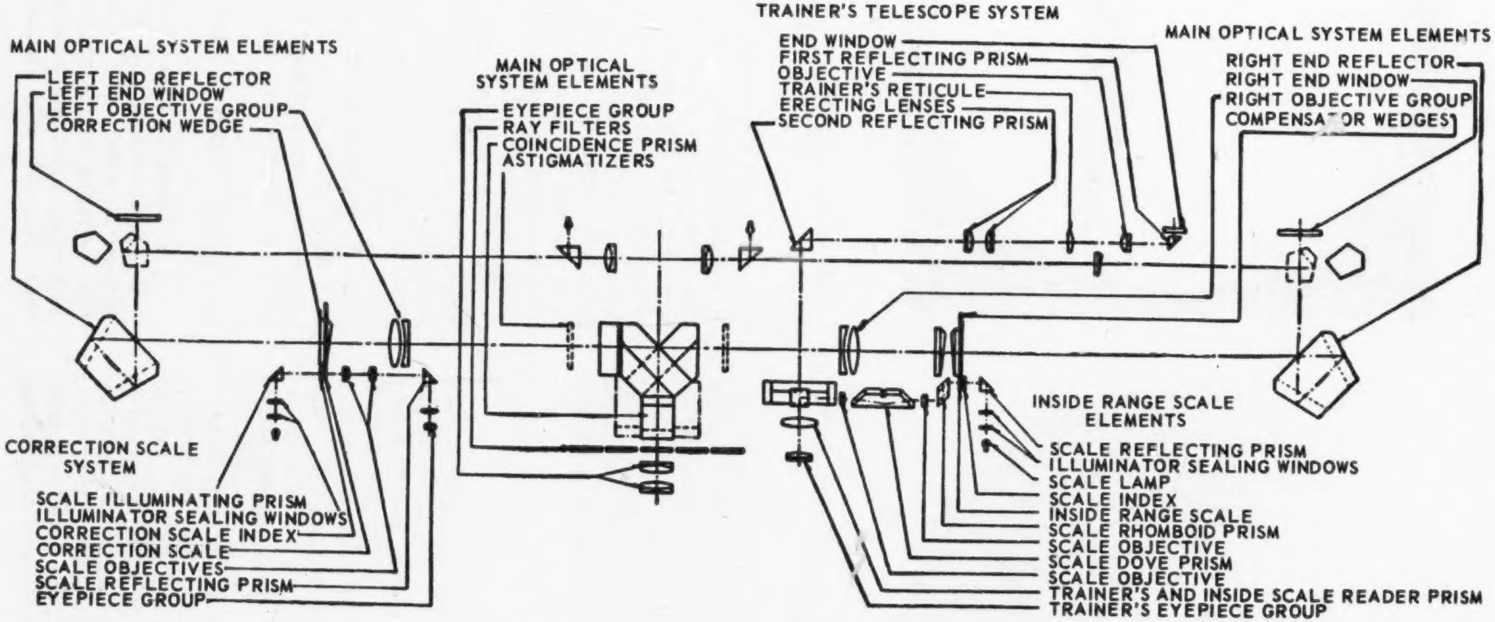
An end window is mounted in the front of each end box of the rangefinder. These windows are tightly sealed around the edges, and thus help to keep dirt and moisture out of the instrument. Although the two surfaces of each window have been ground optically flat, they are not quite parallel. Each end window is actually a prism, though a prism of extremely small angle.

By a suitable rotation of an end window, you can make its deviation zero in the plane of triangulation, or you can deviate the incident rays slightly, to either the right or the left. (As you remember from your study of plane geometry, a line and a point determine a plane. The plane of triangulation is the plane determined by the halving line of the rangefinder and the sighting point on the target.) Since the end windows can deviate the incident rays, they provide a means of compensating for slight inaccuracies in the reflecting angles of the penta prism, or elsewhere in the instrument. There is an index, and in some instruments a graduated scale, on the outer edge of each end window, or on its frame, to show the setting. (On some rangefinders, the left end window is plano-parallel; only the right end window is used for corrections on these instruments.)

The end windows are set during the final inspection of the rangefinder, after it is manufactured, and after each overhaul. When the rangefinder has become thoroughly stabilized at normal temperature, the inspector checks the internal adjustment, and then rotates one or both end windows to secure a correct reading on an accurately known range. It should not be necessary to reset the end windows in service.

End Penta Prisms or End Reflectors

The penta prisms or end reflectors (often called penta reflectors) deviate the line of sight through an angle of 90°. (In most rangefinders, the deviation in the right penta prism or end reflector, although constant, is slightly less than 90°. We will explain why a little later in


MAIN OPTICAL SYSTEM ELEMENTS
LEFT END REFLECTOR
LEFT END WINDOW
LEFT OBJECTIVE GROUP
CORRECTION WEDGE
MAIN OPTICAL SYSTEM ELEMENTS
EYEPIECE GROUP
RAY FILTERS
COINCIDENCE PRISM
ASTIGMATIZERS
TRAINER'S TELESCOPE SYSTEM
END WINDOW
FIRST REFLECTING PRISM
OBJECTIVE
TRAINER'S RETICULE
ERECTING LENSES
SECOND REFLECTING PRISM
MAIN OPTICAL SYSTEM ELEMENTS
RIGHT END REFLECTOR
RIGHT END WINDOW
RIGHT OBJECTIVE GROUP
COMPENSATOR WEDGES
CORRECTION SCALE SYSTEM
SCALE ILLUMINATING PRISM
ILLUMINATOR SEALING WINDOWS
CORRECTION SCALE INDEX
CORRECTION SCALE
SCALE OBJECTIVES
SCALE REFLECTING PRISM
EYEPIECE GROUP
INSIDE RANGE SCALE ELEMENTS
SCALE REFLECTING PRISM
ILLUMINATOR SEALING WINDOWS
SCALE LAMP
SCALE INDEX
INSIDE RANGE SCALE
SCALE RHOMBOID PRISM
SCALE OBJECTIVE
SCALE DOVE PRISM
SCALE OBJECTIVE
TRAINER'S AND INSIDE SCALE READER PRISM
TRAINER'S EYEPIECE GROUP

148.15

Figure 5-10.—Optics of the coincidence rangefinder.

57

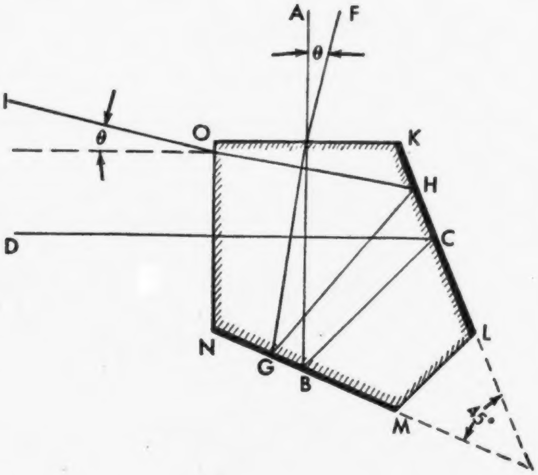
this chapter.) A penta prism, by reflecting the image twice, produces an erect, normal image. We could not use a plane mirror or a right-angle prism for this purpose, because the image would be reverted. In addition, the deviation of a right-angle prism is not constant—it is 90° only if the incident light is normal to the first surface.

In large, long-base rangefinders, the objective lens must be quite large to make the field of view wide enough. In these instruments we use end reflectors, rather than penta prisms. An end reflector consists of two plane mirrors, rigidly mounted together at an angle of 45°. (The rangefinder in fig. 5-10 uses end reflectors, rather than penta prisms.) The path of light within it is the same as that in a penta prism. Figure 5-11 shows the path of light through a penta prism. A study of this diagram will show you that the deviation is constant, regardless of the angle of incidence. Although the light is refracted at both outside surfaces, the two refractions are equal and in opposite directions. Since we can disregard this surface refraction, you can see that an end reflector works in exactly the same way.

In a long-base rangefinder, the end reflector has two advantages over the penta prism. First, a penta prism of sufficient size would be very expensive. Second, and more important, a large end reflector responds quickly to temperature changes; after a change in temperature, the end reflector stabilizes within a short time. A large penta prism, on the other hand, responds slowly, since glass is a poor conductor of heat. For some time after a temperature change, various parts of a large penta prism would be at various temperatures, with resulting distortion and inaccuracy.

Measuring Wedge or Compensator Wedges

Look back at figure 5-7 and review the function of the measuring wedge or compensator wedges. To summarize: they are thin, achromatic prisms, that can be used to deflect the line of sight in one telescope back through the angle θ, so that the two images coincide. There are two general types of deviating wedges: (1) a single measuring wedge, mounted so that you can slide it along the optical axis of the instrument; and (2) two compensator wedges, so mounted that when you turn the ranging knob the two wedges rotate equally and simultaneously, in opposite directions, about the optical axis.



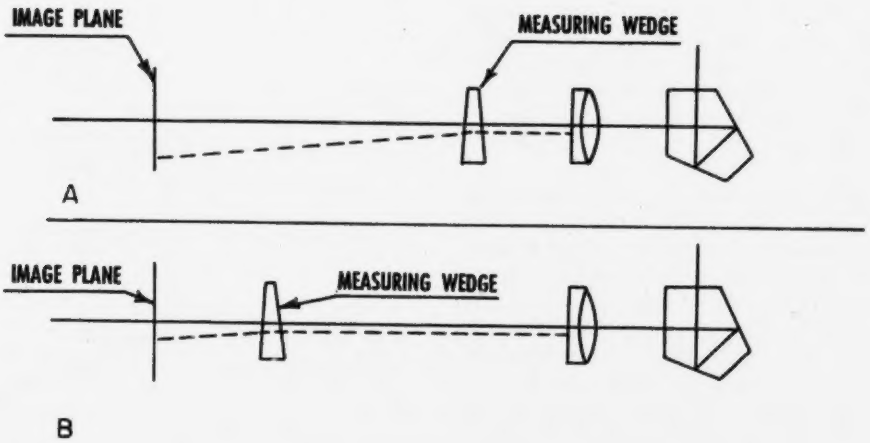
148.16

Figure 5-11.—Principle of the penta prism and end reflector.

Figure 5-12 illustrates the action of a single measuring wedge. It is mounted on the longitudinal axis of the instrument, between the objective lens and its image plane. As you can see in the illustration, the deviation of the wedge is constant. But the displacement of the line of sight, at the image plane, depends on the position of the wedge along the axis. For any angle θ, and therefore for any range, there is a certain position of the wedge on the axis that will make the two images coincide. We can use this system to measure ranges by rigidly attaching a pointer to the wedge, and allowing that pointer to travel over a fixed scale. We can calibrate that scale by marking the position of the pointer when we make coincidence on targets at accurately known ranges.

All of the newer instruments use a pair of compensator wedges. The two compensator wedges are mounted on the axis of the right-hand telescope, outboard of the objective. Figure 5-13 shows a single prism in the position of the compensator wedges.

The incident ray, as usual, diverges from the axis by the angle θ. The prism will deviate that ray toward the base. For any given angle θ, we can select a prism with exactly the deviation necessary to make the incident rays parallel to the axis when they strike the objective. When the rays are parallel to the axis at



148.17

Figure 5-12.—Action of the single measuring wedge.

the right objective (as they are at the left objective), the two images will coincide.

As we have said before, we could use this system to measure ranges by trial and error. If we had a large assortment of prisms handy we could try them out, one by one, until we found one with exactly the deviation necessary to make the rays parallel to the axis. The paired compensator wedges make ranging practical by providing a continuously variable deviation.

Any prism, as you know, will deviate the incident rays toward its base. With the base toward the target (as in fig. 5-13), or toward the operator, all the deviation will be in a horizontal plane. If the base were up or down, all the deviation would be in a vertical plane. If we turn the base to some angle between zero and 90°, the rays will be deviated both horizontally and vertically at the same time.

Figure 5-14 shows what happens when you rotate a single wedge about the optical axis. We have used a screen to intercept the deviated ray, to show what happens to it. The line AO shows the total deviation of the ray toward the base of the prism, CA is the vertical component of the deviation, BA the horizontal component. If you keep the wedge at a fixed distance from the screen, then the total deviation OA will be constant, regardless of the angle of rotation. But as you rotate the wedge the horizontal and vertical components will change. The horizontal component of deviation, BA, is the one we need to reduce the parallactic angle to zero. We will have to eliminate the vertical deviation entirely; otherwise the halving line will fail to split the image—the images will be spread out, or they will overlap.

By using two wedges, rotating through equal angles but in opposite directions, we can keep the horizontal deviation and eliminate the vertical deviation. Figure 5-15 shows how compensator wedges work. You can understand the principle easily if you remember that a prism always deviates the ray toward its base.

Since the range is always large compared to the base of the rangefinder, the parallactic angle is always small. The compensator wedges, therefore, are prisms of very low power—the angle is sometimes so small you can not tell which side of the disk is its base. For this reason a small mark is etched at the edge of most wedges. It represents a line from the center of the base to the apex of the prism.

Earlier in this chapter, we told you that the deviation in the right-hand penta prism or end

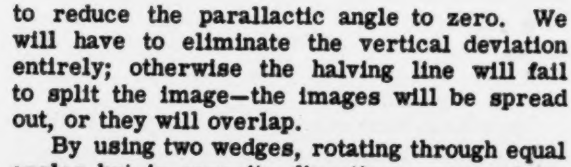


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Figure 5-13.—Action of the compensator wedges.

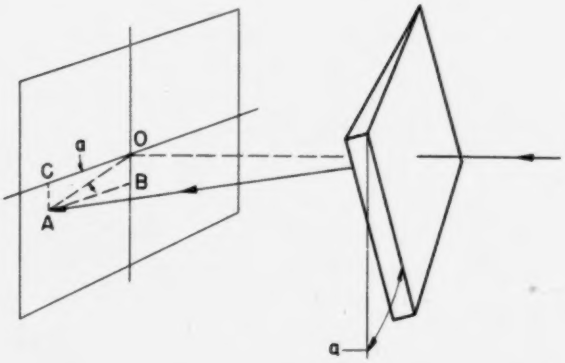

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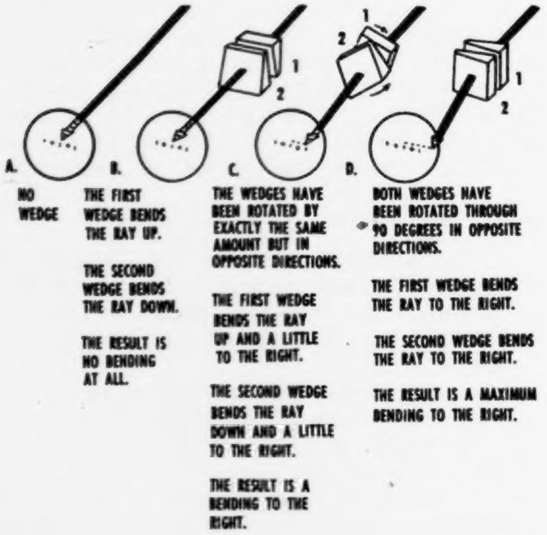
Figure 5-14.—Effect of rotating a single wedge.


1
2
1
2
1
2
A.
NO WEDGE
B.
THE FIRST WEDGE BENDS THE RAY UP.
THE SECOND WEDGE BENDS THE RAY DOWN.
THE RESULT IS NO BENDING AT ALL.
C.
THE WEDGES HAVE BEEN ROTATED BY EXACTLY THE SAME AMOUNT BUT IN OPPOSITE DIRECTIONS.
THE FIRST WEDGE BENDS THE RAY UP AND A LITTLE TO THE RIGHT.
THE SECOND WEDGE BENDS THE RAY DOWN AND A LITTLE TO THE RIGHT.
THE RESULT IS A BENDING TO THE RIGHT.
D.
BOTH WEDGES HAVE BEEN ROTATED THROUGH 90 DEGREES IN OPPOSITE DIRECTIONS.
THE FIRST WEDGE BENDS THE RAY TO THE RIGHT.
THE SECOND WEDGE BENDS THE RAY TO THE RIGHT.
THE RESULT IS A MAXIMUM BENDING TO THE RIGHT.

148.18

Figure 5-15.—Refracting a ray of light with two compensator wedges.

reflector is less than 90°. To understand why, first consider what would happen if the deviation were exactly 90°. Then, for a target at infinity, the incident ray would be deviated parallel to the optical axis. Since the parallactic angle is zero, we would need no deviation in the compensator wedges to make the two images coincide. For a target at infinity, we would turn the base of one wedge up and the base of the other one down, as in part B of figure 5-15.

For a target at the minimum measurable range, the incident rays would deviate from the optical axis, toward the operator, at the maximum parallactic angle. To make them parallel to the axis we would require maximum deviation away from the operator; consequently we would turn the compensator wedges so that both their bases were toward the target. Obviously no rangefinder can measure a range greater than infinity, or less than the mimimum measurable range. To cover the whole span of measurable ranges, we need only rotate the wedges through 90°; and all measurable ranges will be crowded into 90° on the scale.

We could read the scale more accurately if we could expand the calibrations to cover 180°. We can do that quite easily, just by making the deviation in the right penta prism or end reflector less than 90° (by making the angle between the two reflecting surfaces less than 45°). Now, rays from a target at infinity will be deviated away from the axis, back toward the target. To make the images coincide we would turn the wedges so that both bases were toward the operator. For a target at mean range, the incident rays would be parallel to the axis after deviation by the penta prism or end reflector. They would require no deviation at the wedges; we would turn one wedge base up and the other wedge base down. At minimum range we would have maximum deviation toward the operator, and we would compensate for it by turning both wedge bases toward the target. In this system, as you can see, we need 180° of rotation of the wedges to cover the full span of measurable ranges. And consequently the calibrations will be spread through 180° on the scale.

Correction Wedge

The correction wedge provides a means for correcting errors in alignment. Like the measuring wedge, the correction wedge is a thin prism of low power. In some instruments it is achromatic; in others it is a simple prism. It is located in the left-hand telescope, and mounted so that it can be rotated by the operator. Rotation of the wedge, of course, deviates the line of sight, both vertically and horizontally. The deviation in the plane of triangulation is the most useful; errors in horizontal alignment are corrected by adjustment of the optical bars, or adjustment of the height adjuster linkage which raises and lowers the end of the optical bar.

Rangefinder operators sometimes disagree as to when the two halves of the image coincide. An operator may find that he habitually makes an error in ranging, and that this error is fairly constant. With experience he can learn the usual amount of his habitual error, and adjust the correction wedge to correct it.

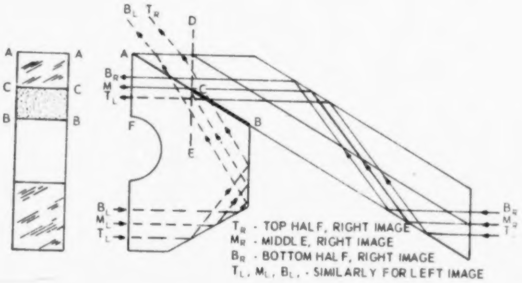
Coincidence Prism

The coincidence prism is the element that suppresses opposite halves of the two images, and presents the composite image to the operator's eye. At the same time, it erects the image.

The coincidence prism is built up of several smaller prisms cemented together and mounted near the center of the instrument. The coincidence prism is complex; it is difficult to describe, and almost impossible to represent satisfactorily in a drawing. To understand it, we suggest that you first read through the rest of this section; then get a cemented coincidence group in your hand, and study it carefully.

Figure 5-16 shows, in a two-dimensional drawing, the path of light through a simple coincidence prism. The prism in the drawing is made up of two smaller prisms, cemented at the surface AB. Before cementing, half of that surface, CB, was silvered. The two sets of rays entering the prism from the two rangefinder telescopes are labled. Follow the rays to see what happens to the right-hand image. The top half will strike the silvered surface, and be reflected up out of the prism; the bottom half will miss the silvered surface, and pass on through to the eyepiece, forming the bottom half of the composite image. The top half of the left image will be reflected, at the silvered surface, toward the eyepiece, and will form the top half of the composite image. The bottom half of the left image will miss the silvered surface and pass on out through the top of the prism.

The middle rays meet at the halving line, in the center of the image. By careful adjustment of the two telescope systems, we can reduce the width of the halving line practically to zero, and thus make coincidence more accurately.


B_L
T_R
D
A
A
A
C
C
B
B
B_R
M
T_L
C
B
F
E
B_L
M_L
T_L
T_R - TOP HALF, RIGHT IMAGE
M_R - MIDDLE, RIGHT IMAGE
B_R - BOTTOM HALF, RIGHT IMAGE
T_L, M_L, B_L, - SIMILARLY FOR LEFT IMAGE
B_R
M_R
T_L

148.19
Figure 5-16.—Principle of the coincidence prism.

Objective Lenses

The function of the objectives is to form real images of the target on the reticles. The objectives are made and mounted with the greatest of precision. If the focus of the objectives are not exactly alike, the magnification of the image in the right and left eye will differ and the range readings will be incorrect. Lack of uniformity in the focus of objectives is readily detected when a target is observed that is not in the center of the field. The right and left objective lenses are therefore selected and adjusted to give the same focus. They are composed of a positive lens of crown glass and a negative lens of flint glass. The objective mounting and the spacing between them must be carefully adjusted to give the correct focus, and they must be held firmly in their mounts without strain.

Eyepiece Group

The eyepiece group is used to view, and to magnify, the composite image reflected by the coincidence prism. The eyepiece has a focusing mount; the usual focusing range is from plus 2 to minus 4 diopters.

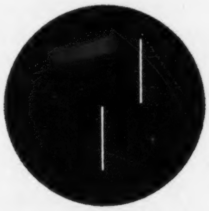
You will find several different types of eyepieces in the various marks of Navy rangefinders. The two most common are:

1. The orthoscopic eyepiece (composed of a cemented triplet and a single lens).
2. The achromatic eyepiece (composed of two cemented doublets, with an air space between them). The newer instruments are provided, almost exclusively, with the achromatic eyepiece.

Astigmatizers

The two astigmatizers—one in each telescope—are mounted on the objective side of the coincidence prism. You can throw them simultaneously to the IN position, where they intercept the rays just before they reach the coincidence prism, or to the OUT position, off the axis, where they have no effect on the image.

Each astigmatizer is a simple lens, but with its surface ground to cylindrical, rather than spherical shape. As you may remember, a cylindrical lens produces an elongated image—the image of a single point will appear as a line. The astigmatizers are useful when you are ranging on a searchlight at night. Here your target image is practically a point of light. You would have to manipulate the rangefinder very carefully to get that point image exactly on the halving line, and even then you could never be sure you had made exact coincidence. When you throw the astigmatizers to the IN position, the two half-images of the searchlight become vertical lines of light, perpendicular to the halving line as in figure 5-17. To make exact coincidence you need only turn the ranging knob until the two half-images form a single, unbroken vertical line.



148.20

Figure 5-17.—Astigmatized half-images of a searchlight.

Color Filters

The color filters are mounted between the coincidence prism and the eyepiece. You will find various color assortments in the various marks of rangefinder. These filters have the same function they have in a telescope: they serve to dim a too brilliant image; they help to reduce haze; under some conditions they increase the contrast of your target against its background.

STEREOSCOPIC RANGEFINDER

Like the coincidence rangefinder, the stereoscopic rangefinder uses a measuring wedge, or a pair of rotating compensator wedges, to measure the parallactic angle; it shows the result on a scale calibrated to indicate the range in yards. The two instruments differ in the way the operator determines when the wedges are correctly set. In the coincidence rangefinder he makes two half-images coincide; in the steroscopic rangefinder he depends on his own stereoscopic vision.

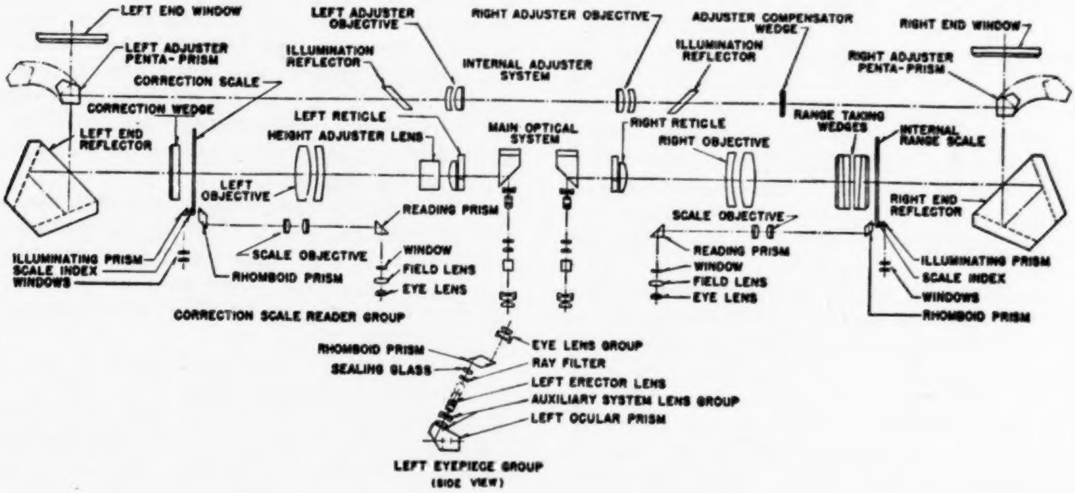
The stereoscopic rangefinder has two eyepieces; the operator's right eye sees the image formed by the right-hand telescope; his left eye sees the other one. The two images fuse together, just as they do when you look through a pair of binoculars.

In each of the two telescopes, in the focal plane of the objective lens, is a reticle. The images of these two reticles, like the two target images, appear to fuse and form a single image. The two reticles are similar, but not identical. Consider, for a moment, a single mark near the center of each reticle. The operator sees a separate mark with each eye; he fuses the two images so that he sees a single mark. But rays from corresponding points on the two marks, as they enter the two eyepieces, are not parallel; they diverge at a small angle. This angle corresponds to a parallactic angle. To the operator, viewing the two marks steroscopically, they appear as a single mark located at a finite distance in space.

Rays from the target, reaching the two eyepieces through separate telescopes, also diverge at a small angle—the parallactic angle of the target. If the parallactic angle of the reticle marks is smaller than that of the target, the fused reticle image will appear to be more distant than the target; if the parallactic angle of the reticle is greater than that of the target, the reticle will appear to be closer.

By rotating the compensator wedges you can change the apparent parallactic angle of the target. In the coincidence rangefinder you reduce it to zero; in the stereoscopic rangefinder you make it equal to that of the reticles. The target and the reticle mark then appear to be at exactly the same distance. The amount of rotation of the wedges necessary to make the two angles equal is a measure of the parallactic angle of the target; consequently, the scale can be calibrated to show the range in yards.

Figure 5-18 shows the optics of a steroscopic rangefinder. As you can see, they are similar to those of the coincidence type, except


LEFT END WINDOW
LEFT ADJUSTER PENTA-PRISM
CORRECTION SCALE
CORRECTION WEDGE
LEFT END REFLECTOR
LEFT ADJUSTER OBJECTIVE
ILLUMINATION REFLECTOR
INTERNAL ADJUSTER SYSTEM
LEFT RETICLE
HEIGHT ADJUSTER LENS
LEFT OBJECTIVE
MAIN OPTICAL SYSTEM
READING PRISM
SCALE OBJECTIVE
WINDOW
FIELD LENS
EYE LENS
ILLUMINATING PRISM
SCALE INDEX
WINDOWS
RHOMBOID PRISM
CORRECTION SCALE READER GROUP
RIGHT ADJUSTER OBJECTIVE
ADJUSTER COMPENSATOR WEDGE
ILLUMINATION REFLECTOR
RIGHT END WINDOW
RIGHT ADJUSTER PENTA-PRISM
RIGHT RETICLE
RIGHT OBJECTIVE
RANGE TAKING WEDGES
INTERNAL RANGE SCALE
RIGHT END REFLECTOR
SCALE OBJECTIVE
READING PRISM
WINDOW
FIELD LENS
EYE LENS
ILLUMINATING PRISM
SCALE INDEX
WINDOWS
RHOMBOID PRISM
RHOMBOID PRISM
SEALING GLASS
EYE LENS GROUP
RAY FILTER
LEFT ERECTOR LENS
AUXILIARY SYSTEM LENS GROUP
LEFT OCULAR PRISM
LEFT EYEPIECE GROUP (SIDE VIEW)

55.300

Figure 5-18.—Optics of the stereoscopic rangefinder.

for the central elements. We will list the principal parts in two groups:

1. End windows, end reflectors or penta prisms, measuring wedge or compensator wedges, objective lens groups, correction wedge, eyepiece groups, and color filters.

2. Height adjuster, ocular prisms, reticles, rhomboid prisms, collective lenses, and erector lenses.

In some instruments the erectors also serve as change-of-magnification lenses. There is no astigmatizer; since there is no halving line, you do not need it. All the elements in group 1 above are the same as those of the coincidence rangefinder. We will not describe them again. The elements in group 2 are found only in the stereoscopic type:

Height Adjuster

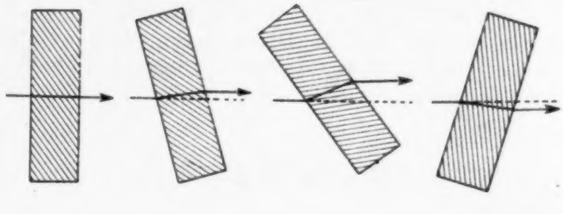
What happens when a ray of light passes through a flat plate of glass? If the ray is normal to the surface, it passes through without any change. If it strikes the surface at a smaller angle, the emergent ray is displaced to one side, though it is still parallel to the incident ray. Figure 5-19 illustrates this principle.

In the stereoscopic rangefinder, the height adjuster is a flat disk of glass in the left-hand optical system. The disk is mounted in bearings, and connected to a knob outside the rangefinder. The operator, by turning the knob and thus tilting the height adjuster, can raise or lower the left-hand target image.

The stereoscopic rangefinder uses its height adjuster for aligning the two optical systems in the horizontal plane, and its correction wedge for vertical alignment.

Ocular Prisms

The two ocular prisms, one for each telescope, are mounted near the center of the instrument. Each prism reflects the image twice, and presents an erect and normal image to the eyepiece. In the newer, double-purpose rangefinders, the prism elevates the line of sight so that, if the lines of sight from the end windows are horizontal, the operator must look downward in order to see the target image.



55.299

Figure 5-19.—Principle of the height adjuster.

(In the Mk 42, the operator's line of sight is downward at an angle of 25° from the vertical.)

Reticles

The reticles are plano-parallel glass disks with reference marks etched on them. They are usually mounted in the focal plane of the objective lenses. In some rangefinders, each reticle is cemented to a convex-plano lens. In most of the recent instruments you will find several sets of reference marks engraved on the reticles. Figure 5-20 shows a typical reticle pattern. (We've added the lettering and arrows to help explain the pattern. On the reticle itself you will see only the vertical marks and the diamonds.)

As we have told you, the two reticles are slightly different; the operator fuses the two reticle images stereoscopically. All the diamonds appear to be at the same distance; the operator can use any one of them as a reference mark in measuring the range. All the marks in any one horizontal row appear to be at the same distance. But the various rows appear to be at various distances: to the operator, the upper rows appear to be more distant than the diamonds; the lower rows appear closer than the diamonds. The marks in the first rows above and below the diamonds are so spaced that their apparent distance from the diamonds is equal to 50 units of error. (A unit of error is the greatest theoretical distance by which a range reading may be wrong.) The second rows from the diamonds appear to have a range difference of 100 units of error.

In ranging, the operator rotates the compensator wedges until the diamonds and the target appear to be at the same distance. He need not change this setting to measure the distance from the target of a burst or splash. By using the vertical marks for reference, the operator can estimate the spot in units of error, which can then be converted to the equivalent in yards for that particular range.

The spacing, from center to center, between any two adjacent marks in the same row, corresponds to five mils in deflection. Thus the operator can quickly make deflection spots without training the rangefinder off his target. (A mil is a unit of measurement for angles, much smaller than a degree—1/6400 of the circumference of a circle.)

Rhomboid Prisms

The rhomboid prisms provide a variable interpupillary adjustment. They are so mounted that the distance between their forward faces remains constant. They pivot about a point at the center of the forward face; thus the distance between the rear faces is variable, and can be set for the operator's interpupillary distance.

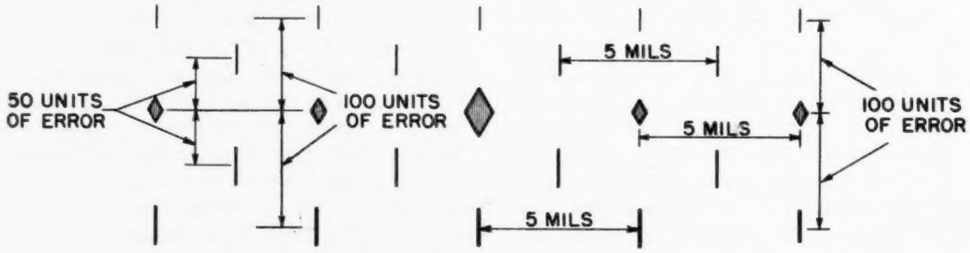
Each collective lens (sometimes called field lens) gathers light from a rhomboid prism and bends it toward the eyepiece lens.

AUXILIARY OPTICAL SYSTEMS

In most rangefinders—both coincidence and stereoscopic—you will find several auxiliary optical systems, in addition to the main system. Some of these are used in ranging; others provide a means for adjusting the main optical system. The principal auxiliary systems are: the internal adjuster system, the adjuster scale reading system, the main scale reading system, and the trainer and finder telescope system.

MAIN SCALE READING SYSTEM

The main scale reading system is used to read the two range scales: the internal scale



55.304

Figure 5-20.—A typical reticle pattern.

64

connected to the wedges, and the external scale mechanically linked to them. In some instruments the system is so arranged that the operator can see the scale along one side of the field; in others, an assistant rangefinder operator reads the scale through an auxiliary telescope built into the rangefinder. As shown in figure 5-18, the reading telescope consists of an arrangement of prisms, a transparent scale, an objective lens, a field lens, and an eye lens. The window in the illuminating system protects the airtight seal of the rangefinder.

The external range scale is a second dial, mounted near the outside of the rangefinder tube, so that it can be read through a window without artificial light.

The internal scale is the more important of the two; normally the operator will read only the internal scale. The external scale is provided for use if the illuminating circuit for the internal scale should fail. In inspecting a rangefinder you should check to be sure that both scales give the same reading. If they do not, you will probably find some lost motion in the mechanical linkage; or the coupling between the external scale and the wedges may be out of adjustment.

INTERNAL ADJUSTER SYSTEM

The internal adjuster system provides an artificial target, inside the instrument, which can be used to check the range scale. The optics are so arranged that the light from the artificial target, on entering the two main telescopes, appears to come from infinity, or from some selected standard range. The range scale is set for this known distance, and then the wedges are adjusted to give coincidence (or stereoscopic contact) on the artificial target.

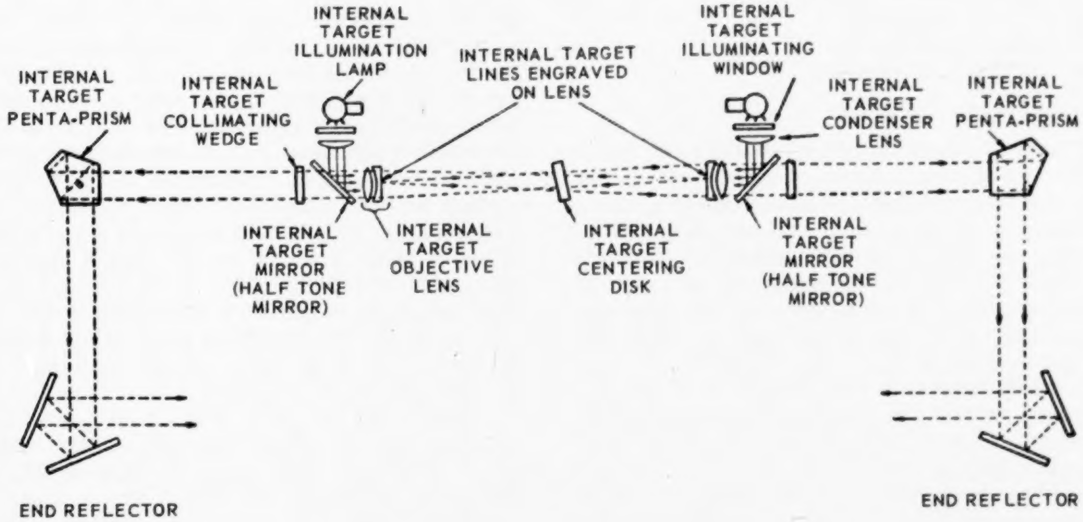
A study of figure 5-21 will show you how the system works. The system consists of two objective lenses, located in an adjuster tube mounted alongside the main optical tube of the rangefinder. The objectives are of the same focal length, and they are so spaced that each is at the front focal point of the other. Cemented to each objective is a reticle on which the artificial target—usually two vertical lines—is etched. Thus each target is in the focal plane of the opposite objective. A transparent reflector plate is mounted outboard of each objective.

First, consider the left-hand reflector alone. Light from a small lamp, mounted on the outside of the rangefinder, enters through a window, is reflected from the reflector plate, and illuminates the left target mark. Since this mark is in the focal plane of the right objective, rays from the mark will be parallel after they pass through the right objective. Some of this light will be reflected by the right reflector, and be lost; the rest will pass through. At the same time, the right target mark is illuminated by the right reflector, and sends out rays which become parallel after passing through the left objective.

At each end of the adjuster tube is a small penta prism. Ordinarily these prisms are swung out of the way, so as not to interfere with the operation of the main optical system. By turning the internal adjuster drive knob, you can crank the two penta prisms into position. This operation automatically closes the shutters over the end windows, to keep external light out of the system.

If the two objectives of the internal adjuster system are so mounted that their optical axes coincide, then the two sets of rays from the two internal targets will both be parallel to that axis. And, after reflection at the two small penta prisms, the two sets of rays will still be parallel to each other. In the stereoscopic rangefinder, the operator will see one target with each eye, and the two images will fuse stereoscopically.

Remember that the deflection in the right-hand penta prism or end reflector is usually less than 90°. This angle differs somewhat in different marks of rangefinders. The angle of deviation of both internal adjuster penta prisms is 90°. So there is one prescribed range at which the scale must be set in order to check its calibration with the internal adjuster system. The operator sets the range scale at this prescribed distance, and then sights through the eyepiece (or eyepieces). In the stereoscopic rangefinder the image of the artificial target must appear to be at the same distance as the ranging mark on the reticles. If it doesn't, the operator must turn the correction knob until it does. He repeats this operation five times, then sets the median correction on the range scale. (With a coincidence rangefinder, of course, the operator must adjust the scale so that the two half-images of the artificial targets make coincidence at the halving line when the range scale indicates the prescribed range.)


INTERNAL TARGET PENTA-PRISM
INTERNAL TARGET COLLIMATING WEDGE
INTERNAL TARGET ILLUMINATION LAMP
INTERNAL TARGET LINES ENGRAVED ON LENS
INTERNAL TARGET ILLUMINATING WINDOW
INTERNAL TARGET CONDENSER LENS
INTERNAL TARGET PENTA-PRISM
INTERNAL TARGET MIRROR (HALF TONE MIRROR)
INTERNAL TARGET OBJECTIVE LENS
INTERNAL TARGET CENTERING DISK
INTERNAL TARGET MIRROR (HALF TONE MIRROR)
END REFLECTOR
END REFLECTOR

148.21

Figure 5-21.—Internal adjuster system.

On the stereoscopic rangefinder, the internal adjustment is easier to make if the ranging mark on the reticle is centered between the two vertical lines of the artificial target. If it is not centered, turn the internal target adjuster knob (sometimes called the collimator knob) to center it. The artificial target should never appear to touch the ranging mark; if it does it will interfere with your stereoscopic judgement.

ADJUSTER SCALE READING SYSTEM

The correction wedge of the internal adjuster system is similar to a single measuring wedge. The adjuster scale reading system enables you to determine the position of this wedge. On some instruments the position of this wedge is shown on a scale attached to it; on others it is indicated on a dial similar to the outside range scale. The system includes a source of illumination, and lenses for magnifying the scale. On all rangefinders later than the Mk 28, the scale is graduated in units of error.

RANGEFINDER OPERATION

It is obvious that rangefinders are precision instruments, since the parallactic angles they measure are extremely small. Suppose, for example, that a target at a range of 6,000 yards moves 18 yards toward you. How much does that change the parallactic angle? In the Rangefinder Mk 42, the parallactic angle would increase by only 0.00014 degrees. Yet, under favorable conditions, this rangefinder can detect that small a change in the parallactic angle.

The elements of the rangefinder must be made and assembled with extreme precision. Any small errors that may be present after assembly can be eliminated by adjustment of the end windows. In addition, the instrument is provided with several checks and adjustments to facilitate accurate ranging. The knobs by which these adjustments are made vary in position on the different marks of rangefinder, and sometimes on different modifications of the same mark. However, the knobs are always labeled.

STEREOSCOPIC RANGEFINDER OPERATION

In the next sections we will discuss the operation of the stereoscopic rangefinder. The operation of the coincidence type is quite similar; we will tell you later how it differs. These are the four basic adjustments of the stereoscopic rangefinder, in the order in which the operator makes them:

1. Interpupillary adjustment.
2. Focus adjustment.
3. Height adjustment.
4. Internal adjustment.

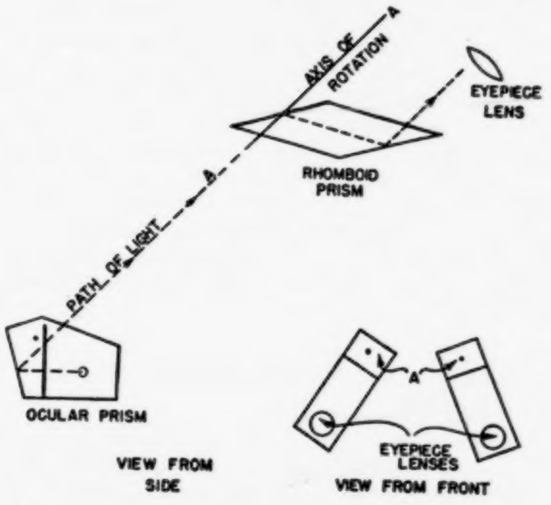
Interpupillary Adjustment

Figure 5-22 shows how the rhomboid prisms enable you to adjust the spacing of the eyepieces. Since the image is reflected twice in each prism, it emerges unchanged. You can see that by pivoting the two rhomboid prisms on the axis A-A you can adjust the distances between the eyepieces. Moving the prisms on this axis does not change the length of the path of light, nor change the orientation of the image in any way.

A small knob or lever, located near the eyepieces, controls the interpupillary adjustment. If you do not know your own interpupillary distance, it might be a good idea to measure it now. Use an accurate interpupillometer and measure to the nearest 1/4 millimeter. Then, whenever you use or inspect a rangefinder, you can set the interpupillary adjustment to the proper value for your eyes.

The operator must make this adjustment very carefully, to within 1/4 millimeter of the proper setting for his eyes. He should then tighten the locknut, if there is one, to keep the setting from changing while the rangefinder is in use. If parallax is present, a small error in the interpupillary setting can cause serious errors in ranging. The greater the parallax of the instrument, the larger the errors will be. Parallax is present, you remember, when the image formed by the objective does not lie exactly in the plane of the reticle. No matter how carefully you adjust the rangefinder during overhaul, a small amount of parallax will nearly always be present. Parallax is sometimes caused by temperature changes; more often, by variations in range. The objective is positioned so that when a target is at median range its image will fall in the plane of the reticle. Thus if a target is at extreme range, its image will fall short (on the objective side) of the reticle; if the target is at close range its image will fall beyond (on the eyepiece side of) the reticle.

When a target is at short range, too small an interpupillary adjustment will result in short range readings; too large an adjustment will make the readings too long. For a target at extreme range you have the opposite effect: a large interpupillary adjustment will make the range readings too short; a small one will make them too long. Figure 5-23 shows what happens when the image falls on the eyepiece side of the reticle.



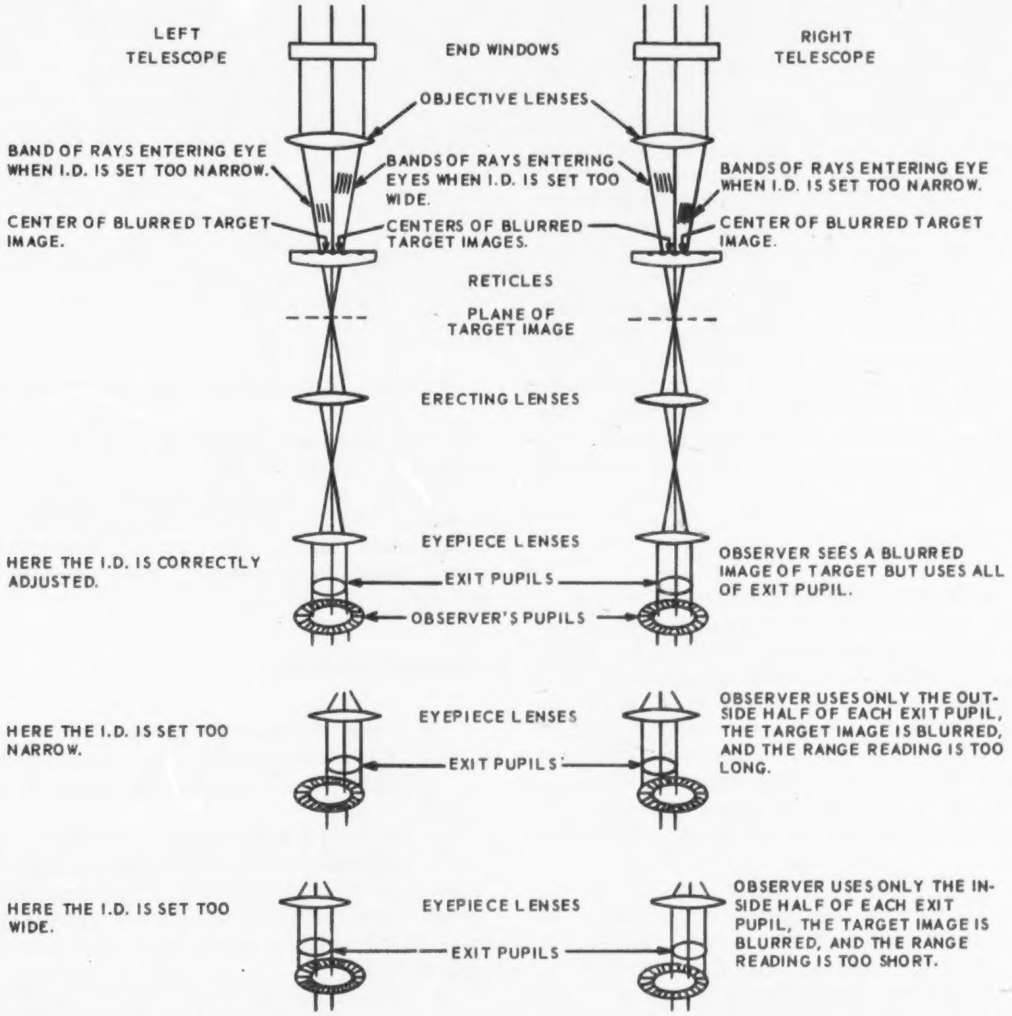
55.298
Figure 5-22.—Interpupillary distance adjustment.

Focus Adjustment

The purpose of the focus adjustment, of course, is to bring the target image sharply into view. Make the adjustment by turning the knurled focusing rings below the eyeguards. The focusing scale is calibrated in diopters. You remember the proper procedure for focusing any telescope: turn the focusing collar to the minus end of the scale, look through the eyepiece, and then turn the collar back toward plus until the image is sharp. This method helps reduce eyestrain in using the rangefinder; the eyes accommodate more readily to a minus setting than to a plus setting.

Focus the eyepieces one at a time. Keep both eyes open while you focus; when you are focusing one eyepiece, have someone cover the other end window, if practicable. Of course if you know the proper setting for your own eyes, and know that the focusing scale of the rangefinder is correctly calibrated, you can instantly set the eyepieces to the proper focus for your eyes.

Although it seems obvious, operators sometimes forget that changing the focus will not


LEFT TELESCOPE
END WINDOWS
RIGHT TELESCOPE
OBJECTIVE LENSES
BAND OF RAYS ENTERING EYE WHEN I.D. IS SET TOO NARROW.
BANDS OF RAYS ENTERING EYES WHEN I.D. IS SET TOO WIDE.
BANDS OF RAYS ENTERING EYE WHEN I.D. IS SET TOO NARROW.
CENTER OF BLURRED TARGET IMAGE.
CENTERS OF BLURRED TARGET IMAGES.
CENTER OF BLURRED TARGET IMAGE.
RETICLES
PLANE OF TARGET IMAGE
ERECTING LENSES
EYEPIECE LENSES
HERE THE I.D. IS CORRECTLY ADJUSTED.
EXIT PUPILS
OBSERVER SEES A BLURRED IMAGE OF TARGET BUT USES ALL OF EXIT PUPIL.
OBSERVER'S PUPILS
EYEPIECE LENSES
OBSERVER USES ONLY THE OUTSIDE HALF OF EACH EXIT PUPIL, THE TARGET IMAGE IS BLURRED, AND THE RANGE READING IS TOO LONG.
HERE THE I.D. IS SET TOO NARROW.
EXIT PUPILS
EYEPIECE LENSES
OBSERVER USES ONLY THE INSIDE HALF OF EACH EXIT PUPIL, THE TARGET IMAGE IS BLURRED, AND THE RANGE READING IS TOO SHORT.
HERE THE I.D. IS SET TOO WIDE.
EXIT PUPILS

148.22

Figure 5-23.—Errors caused by parallax and incorrect interpupillary adjustment.

remedy haze, or darkness, or fogged end windows. The operator should determine the diopter setting for his own eyes, on each instrument he uses, under the best possible conditions. He should use that predetermined setting when conditions are unfavorable for accurate focusing.

Height Adjustment

The height adjustment secures the horizontal alignment of the images in the two rangefinder telescopes. You can change the height adjustment by rotating the height adjuster knob. You will not have to make this adjustment very often, but you should check it each time you use the rangefinder, or whenever you have trouble in fusing the two images.

There are two ways to make the adjustment. In one of these, you aim the rangefinder at the horizon. Keep your eyes on the horizon, and notice the reticle marks without looking at them closely. Turn the ranging knob until you break your stereoscopic fusion of the reticle images, and see two separate images of the recticle pattern. (You will need a little practice before you can do this easily.) Turn the height adjuster knob slowly until the two center marks of the reticle patterns are at exactly the same height above the horizon.

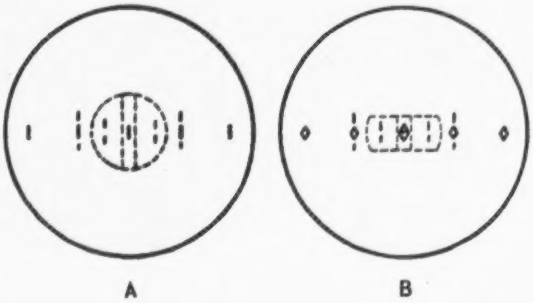
If you are working in the shop, you can use the other method. Cover one of the end windows of the rangefinder and look through the other eyepiece. Train and elevate your rangefinder on some fixed target, and adjust it so that the bottom point of the center reticle mark barely touches the top of the target. Now cover the opposite end window. Train the rangefinder, without elevating or depressing it, to bring the other reticle mark over the same target. Turn the height adjuster knob until the bottom of the mark barely touches the top of the target. This is the more accurate of the two methods, but of course it requires that the rangefinder mount be absolutely stable.

Internal Adjustment

The internal adjuster system provides an artificial target inside the instrument, by which you can check the accuracy of the range scale settings. In using the internal adjuster system, the operator will see a target consisting of two vertical lines, with the center mark of the reticle between them. He then turns the correction knob until the target lines and the reticle mark appear to be at exactly the same distance, and sets the indicated correction on the correction scale.

Figure 5-24, part A, shows the type of internal adjuster target in the Rangefinder Mark 42 Mods 4 and 5. Figure 5-24, part B, represents the target in Rangefinder Mk 42 Mods 6, 8, 9, 10, 11, 12, and 13. In the figure the dotted lines represent the target. (The reticle marks outside the target are not visible when you use the internal adjuster.) These are the steps in making the internal adjustment of the Mk 42 rangefinder:

1. Set the range scale to 6,000 yards. (The range of the internal target is usually marked on a small plate near the range knob, and indicated on the range scale by a small star.) Set the correction scale at its mid-position—marked "60".
2. Turn the adjuster penta prisms to the "in" position.
3. Illuminate the internal adjuster target.
4. By turning the correction knob, range stereoscopically on the internal adjuster target. Repeat this operation five times, and record the correction scale reading each time. Determine the median reading.
5. Set the correction scale to the median reading. To that reading, add (or subtract) your calibration offset. Now, unless temperature or other conditions change, the rangefinder is properly adjusted.



148.23
Figure 5-24.—Reticle and adjuster target.

Other Adjustments

On some instruments you will have to make a few additional adjustments; you will not find all of them on all marks and mods of rangefinders.

1. Headrest adjustment. Adjust it so that your forehead rests comfortably against it when your eyes are at the normal eye-distance. (At normal eye-distance, the rubber eyeguards will rest lightly around your eyes, and exclude all external light.)
2. Color filters. These have the same function as in the coincidence rangefinder. Use them when you need to cut glare or haze, or when you want to increase the contrast of the target against its background.
3. Searchlight filters. These filters, provided on most stereoscopic rangefinders, are extremely dark. Use them when ranging on a searchlight aimed at your ship.
4. Change of magnification. Some rangefinders are provided with two degrees of magnification. Always use the higher magnification unless you need a wider field of view.
5. Reticle rheostat. This controls the illumination of the two reticles. When ranging at night, adjust the reticle illumination to the minimum usable brightness.

Now look back at figure 5-18. See if you can identify all the parts, and describe their function. But do not try to memorize the details of the optical system; the details will vary considerably between the various Marks and Mods. Concentrate on general principles.

Here is a summary of the steps in preparing a steroscopic rangefinder for use:

1. Set the interpupillary adjustment.
2. Set the focus.
3. Adjust the headrest.
4. Check the height adjustment; readjust it if necessary.
5. Make at least five internal adjustments, and use the median correction.
6. Use a filter if visibility is poor.
7. When ranging at night, adjust the reticle illumination.

COINCIDENCE RANGEFINDER OPERATION

In most respects the operation of the coincidence rangefinder is similar to that of the stereoscopic type. Make these adjustments:

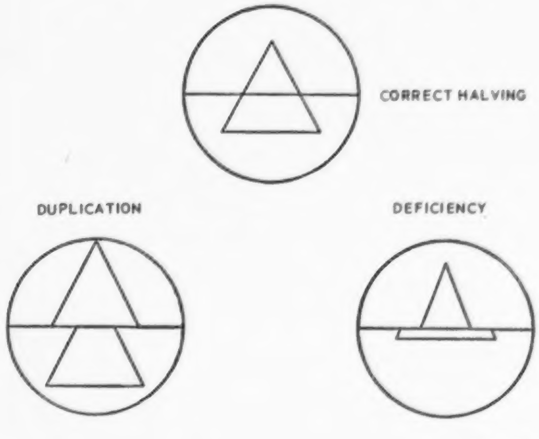
1. Set the focus.
2. Check the halving adjustment; readjust if necessary.
3. Make five internal adjustments; use the median correction.
4. Use a filter if visibility is poor.
5. If ranging on a point of light at night, turn the astigmatizers to the "in" position.

All these adjustments are the same as those of the stereoscopic rangefinder, except the halving adjustment and the use of astigmatizers.

The **HALVING ADJUSTMENT** secures proper alignment of the two half-images, so that the operator sees a single unbroken image, without duplication or deficiency (see fig. 5-25).

In making the halving adjustment, select a target with a small and clearly defined top, of a shape that will not "telescope" easily. (A pyramid or diagonal is most useful; avoid a mast or other vertical structure.) Use the elevation control to move the halving line slowly up and down over the top of the target. Look closely for any duplication or deficiency.

Be sure that, unless you are ranging on a point of light at night, the **ASTIGMATIZERS** are "out." If they are "in," they will give you a blurred and streaky image, and make ranging impossible.



148.24

Figure 5-25.—Effects of duplication and deficiency.

MECHANICAL CONSTRUCTION OF RANGEFINDER

The structural frame of a modern naval rangefinder consists of three long tubes:

THE OUTER TUBE is made of seamless drawn steel, heavily wrapped with insulating material to help minimize the effect of temperature variations on the working parts of the instrument. The outer tube is gastight; it is filled with helium or nitrogen under slight pressure. The gas serves two purposes: it retards aging of the optical glass and cement by keeping oxygen away from them; and since it is dried before the instrument is charged, it prevents condensation of moisture on the inner surfaces.

Near each end of the outer tube is a ring, by which the rangefinder is attached to its mount in a director or turret. Figure 5-26 shows the mechanical construction of a typical stereoscopic rangefinder.

THE INNER TUBE, mounted within the outer tube, is the main structural frame of the instrument; like the outer tube, it is made of seamless drawn steel. Between these tubes is a gas-filled space, which helps to insulate the optical elements against temperature changes. The inner tube carries most of the optical and mechanical working parts; the only important exception is the eyepiece group, which is mounted on the outer tube. The inner tube is mounted in the outer tube on two bearings; the right-hand bearing permits a small amount of

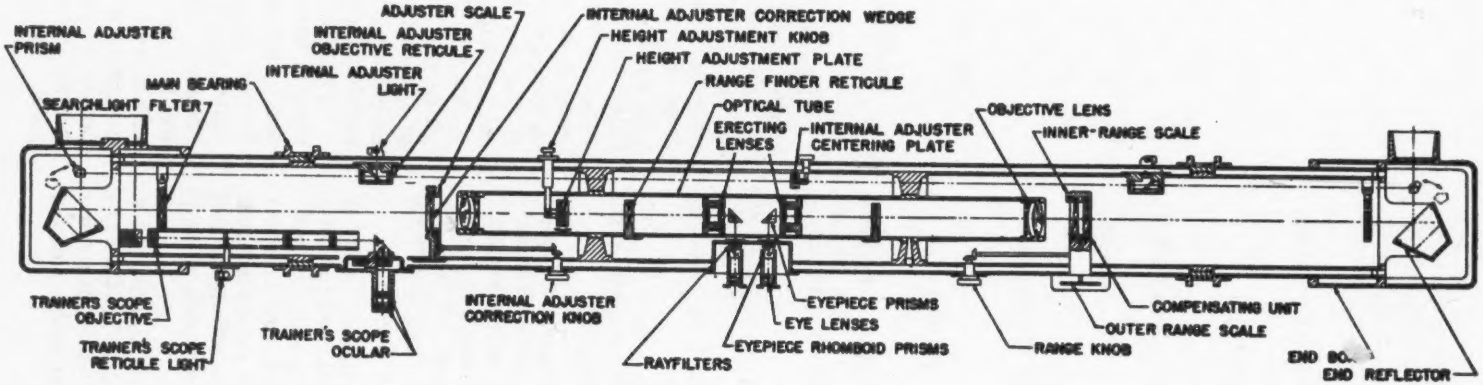

INTERNAL ADJUSTER PRISM
SEARCHLIGHT FILTER
MAIN BEARING
INTERNAL ADJUSTER LIGHT
INTERNAL ADJUSTER OBJECTIVE RETICULE
ADJUSTER SCALE
INTERNAL ADJUSTER CORRECTION WEDGE
HEIGHT ADJUSTMENT KNOB
HEIGHT ADJUSTMENT PLATE
RANGE FINDER RETICULE
OPTICAL TUBE
ERECTING LENSES
INTERNAL ADJUSTER CENTERING PLATE
OBJECTIVE LENS
INNER-RANGE SCALE
TRAINER'S SCOPE OBJECTIVE
TRAINER'S SCOPE RETICULE LIGHT
TRAINER'S SCOPE OCULAR
INTERNAL ADJUSTER CORRECTION KNOB
RAYFILTERS
EYEPIECE RHOMBOID PRISMS
EYE LENSES
EYEPIECE PRISMS
RANGE KNOB
OUTER RANGE SCALE
COMPENSATING UNIT
END BO
END REFLECTOR

Figure 5-26.—Construction of a simple stereoscopic rangefinder.

55.297

movement along the axis of the rangefinder. Thus if the outer tube expands or contracts because of temperature changes or external stresses, it will not distort the inner tube.

THE OPTICAL TUBE or OPTICAL BAR is a short, rigid tube machined from specially treated steel with a low coefficient of expansion. It is perfectly balanced, and bearing-mounted in the inner tube so that it will not be distorted by temperature changes.

Temperature changes, of course, result in expansion or contraction of metal and glass. In an instrument as long as a rangefinder, this could easily result in serious misalignment of the optical parts. As you can see, naval rangefinders are specially constructed to minimize this effect.

CHAPTER 6

RANGEFINDER CALIBRATION AND MAINTENANCE

The primary job of the rangefinder operator is to measure ranges accurately, consistently, and with reasonable speed. To do this job successfully he must have a thorough knowledge of rangefinder adjustments, and continued practice in making them. The Opticalman's primary job is repairing the rangefinder—not operating it. But the OM can do his job more efficiently by becoming thoroughly familiar with the operating technique, and by developing maximum skill as a rangefinder operator. Here are some tips on rangefinder operation:

Do not spend too much time on one range setting. If you make a setting carefully and confidently, it will probably be accurate; if you make a setting hesitantly and then back off a little and try again, it may not be as accurate.

There are two ways to make the range setting: by making the original setting too long, and then turning back to the target; or by making the original setting too short, and then working forward to the target. Decide which of these methods is easier for you. On stationary or slow-moving targets always make the setting in the same direction, whether measuring ranges or calibrating the rangefinder. For a fast-moving target, tracking can be done more smoothly by making the settings in the direction of target motion.

When the range rate is low (that is, the range is changing slowly), you may not notice when the target drifts out of stereoscopic contact with the reticle. Under such conditions it is advisable to break contact, deliberately and frequently. But keep the break small; simply turn the ranging knob a short distance, then remake the contact. For a skilled operator it is unnecessary to bracket both sides of the target, except under very difficult conditions. (When the range rate is high, the target motion itself will break the stereoscopic contact. Simply bring the reticle back on again.)

On most rangefinders there is a range-signal button (buzzer) mounted at the center of the ranging knob. The buzzer is used to signal when a range setting is made. The buzzer is sounded only while the target and reticle are actually in stereoscopic contact.

Practice ranging on moving targets should be done when ranges are being simultaneously measured by some other means, if possible. Such practice will help develop skill as a smooth, fast rangefinder operator, and this skill is invaluable when calibrating the instrument. If a rangefinder is not available for frequent practice, use a stereo trainer. Careful tests show that, in the early stages of training, a man can learn as well on the stereo trainer as on the rangefinder.

Avoid these common errors that cause inaccurate ranging:

1. Interpupillary distance inaccurately set.
2. Focus improperly set. (If one of the images is slightly blurred, it will decrease stereo perception.)
3. Height adjustment improperly set. (This also decreases stereo perception.)
4. Internal adjustment made carelessly, or made with the range scale incorrectly set.
5. Pressing face too hard against the rubber eyeguards.
6. Eyepieces or end windows being dirty.
7. Covering the target with the ranging mark of the reticle. (This interferes with stereoscopic judgment. The ranging mark should appear just above the target, not superimposed on it.)

RANGEFINDER ACCURACY

The operator of a stereoscopic rangefinder makes his range setting by bringing the target and the ranging mark of the reticle to the same apparent distance. When do the two distances appear to be the same? When the two parallactic angles appear to be the same. The accuracy of a stereoscopic rangefinder is limited by the stereo-acuity of its operator. Two angles will appear to be the same, even to a trained operator,

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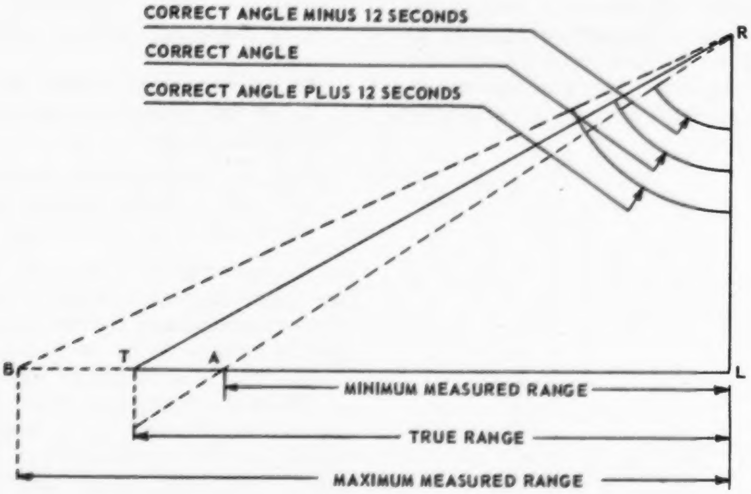


Figure 6-1.—Possible errors in measuring the parallactic angle.

148.25

if there is no more than 12 seconds difference between them. So when even the most skilled operator makes stereoscopic contact with a target, his measurement of its parallactic angle may be off by as much as 12 seconds in either direction.

Look at figure 6-1. Let us assume that a skilled operator is using a stereoscopic rangefinder (LR represents its base line) to range on the target at T. The angle LTR is the true parallactic angle of that target. When the operator turns the ranging knob until the target makes stereoscopic contact with the reticle, he is ready to read the range on the scale. But the parallactic angle he has measured may be in error by as much as 12 seconds in either direction. And this error will be undetectable, no matter how skilled the operator may be.

If he makes the maximum undetectable error on the short side, he will actually measure angle LAR (the true parallactic angle of the target, plus 12 seconds). The range scale will then show the target to be at A, rather than its true position T. If the operator makes the maximum undetectable error on the long side, the range scale will show the target to be at B, rather than at its true position. So a stereoscopic rangefinder does not give the exact position of the target. If the range scale shows the target to be at T, it is actually somewhere between A and B.

When the range scale shows the range to be LT, we know that reading may be wrong, in either direction, by a certain distance. The range error may be any distance that does not change the parallactic angle (as seen through the eyepiece of the rangefinder). The greatest theoretical distance by which a range reading may be wrong (for a given rangefinder, at a given range) is a useful unit of measurement. We call it the UNIT OF ERROR (U.O.E.). In figure 6-1, the distances AT and BT are each equal to one unit of error. (As you can see, BT is slightly longer than AT. But the difference is so small, compared to the error itself, that we can disregard it.)

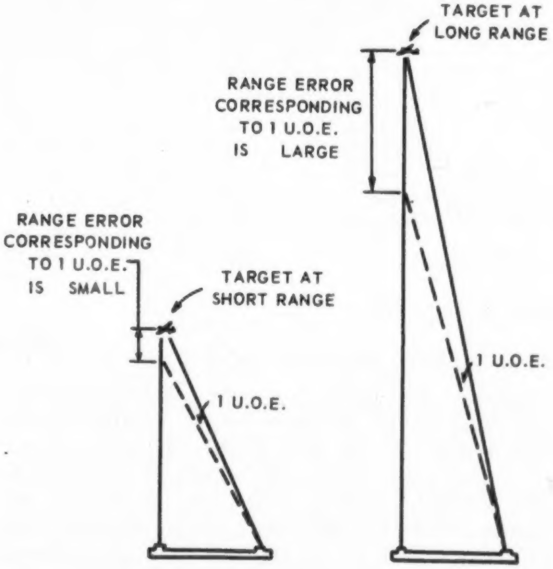
The unit of error also provides a unit for measuring range errors when we spot bursts or splashes. (We cannot measure these errors directly in yards, since the apparent distance between the various rows on the reticle varies with the range.) The U.O.E. also can be used to measure the relative skill of individual operators, since the size, in yards, of an operator's habitual error also varies with range. Consequently, the correction scale is calibrated in units of error. (For a given rangefinder, working at a given range, we can easily convert units of error into yards.)

If the range error caused by one unit of error is a variable number of yards, what determines it? Four things:

First, of course, the stereo-acuity of the rangefinder operator. In order to derive a convenient formula, we assume a constant value—12 seconds—for the stereo-acuity of all trained operators.

Second, the magnification of the rangefinder. Remember that errors are caused by undetectable differences in angles AT THE OBSERVER'S EYE. The apparent parallactic angles are increased by the magnification of the instrument.

Third, the range. Figure 6-2 shows two identical rangefinders, ranging on targets at two different ranges. In each case the angular unit of error (U.O.E.) is the same, but the range error caused by it is much greater at the longer range. The range error increases with the SQUARE of the range in thousands of yards. (For example, assume that for a given rangefinder the unit of error is equal to a range error of 1 yard at a range of 1,000 yards. Then at 2,000 yards the error will be 4 yards; at 3,000 yards it will be 9 yards; etc.).


TARGET AT LONG RANGE
RANGE ERROR CORRESPONDING TO 1 U.O.E. IS LARGE
RANGE ERROR CORRESPONDING TO 1 U.O.E. IS SMALL
TARGET AT SHORT RANGE
1 U.O.E.
1 U.O.E.

148.26
Figure 6-2.—How a range error equal to one U.O.E. changes with range.

Fourth, the base length of the rangefinder. In figure 6-3 are two rangefinders of different base length, ranging on targets at the same range. Although the angular unit of error of the two instruments is the same, it causes a greater range error in the short-base rangefinder.

When spotting the fall of shot in range, the operator reports the range error in units of error. But before he can use that measurement to correct the elevation of the guns, it must be converted into yards. Use the formula:

$$e = \frac{58.2}{BM} \times \left(\frac{R}{1,000}\right)^2$$

Where:

e is the range error, in yards, due to one unit of error
B is the base length of the rangefinder
M is the magnification of the rangefinder
R is the range

58.2 is a constant, valid only when the operator's stereo-acuity is 12 seconds, and when both B and R are expressed in YARDS.

When using this formula, ALWAYS express the base length in YARDS. The base length of some rangefinders is normally stated in feet or meters which must be converted into YARDS before the formula can be used.

Apply the formula in a sample problem. The Mk 14 rangefinder has a base length of 1.094 yards, and a magnification of 11 X. What is the value, in yards, of its unit of error at 1,000 yards? Substitute in the formula:

$$e = \frac{58.2}{1.094 \times 11} \times \left(\frac{1,000}{1,000}\right)^2$$

$$= \frac{58.2}{1.094 \times 11} \times 1$$

$$= 4.83 \text{ yards}$$

So, for this rangefinder, the range error due to one unit of error is 4.83 yards at 1,000 yards. What is it at 2,000 yards? You have already found the value of $\frac{58.2}{BM}$; for any given rangefinder tha quantity remains constant (unless you change the magnification). Then

$$e = 4.83 \times \left(\frac{2,000}{1,000}\right)^2$$

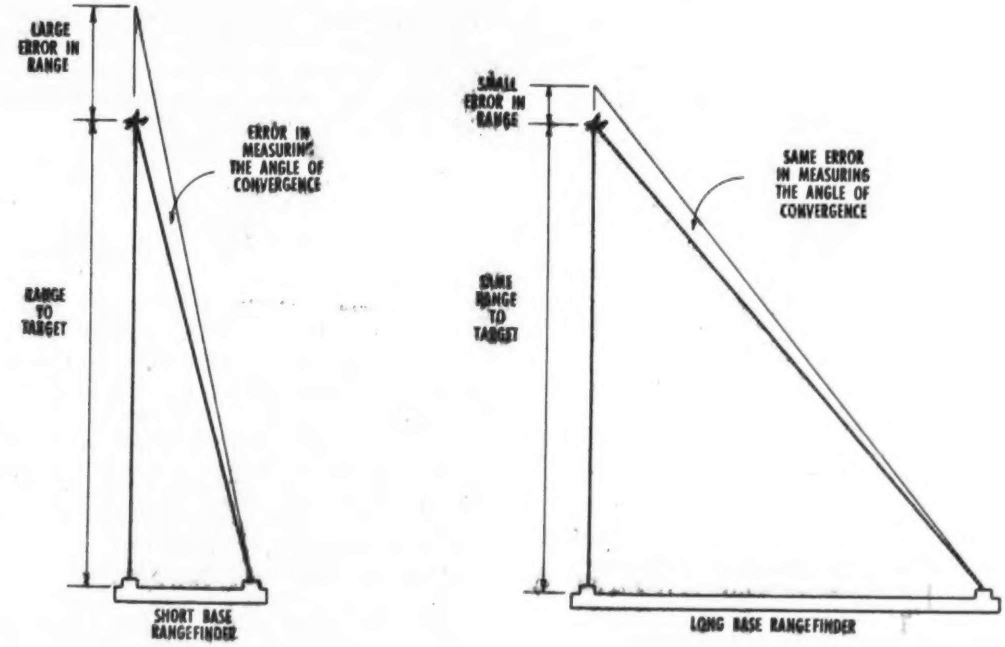
$$= 4.83 \times 4$$

$$= 19.32 \text{ yards}$$

For each rangefinder, the units of error must be converted into yards. There are three ways to do this:

1. By using the tables provided for many rangefinders (in the OP's that describe them) that show the value of the unit of error at various ranges.

2. By calculating the value of the unit of error for any particular range by using the formula. First find the value of the constant $\frac{58.2}{BM}$. Then express the range in THOUSANDS


LARGE ERROR IN RANGE
ERROR IN MEASURING THE ANGLE OF CONVERGENCE
RANGE TO TARGET
SHORT BASE RANGEFINDER
SMALL ERROR IN RANGE
SAME ERROR IN MEASURING THE ANGLE OF CONVERGENCE
SAME RANGE TO TARGET
LONG BASE RANGEFINDER

148.27

Figure 6-3.—How range error due to one U.O.E. varies with base length of the rangefinder.

OF YARDS, square it, and multiply by the predetermined value of $\frac{58.2}{BM}$.

3. By solving the formula for a number of ranges, and then drawing a curve, plotting the value of the unit of error against the range. Thereafter you can make the conversion by spotting the range on the curve, and then reading the corresponding value for the unit of error.

To understand how to derive the unit-of-error formula, look at figure 6-4. In this diagram, B is the base of a rangefinder that is ranging on a target that appears to be at T. R$\theta$is the apparent range of that target, and is its apparent parallactic angle. Now suppose that in measuring the range the operator has made the maximum theoretical error on the near side. Then the target actually lies at T'. Its actual range is R + e, rather than R as shown on the range dial. And its actual parallactic angle is ϕ (the Greek letter Phi).

In chapter 5, we developed the basic rangefinder formula:

$$\theta = \frac{B}{R} \qquad (1)$$

We know that with very small angles, such as the parallactic angle of a rangefinder target, that equation is true when we express e in radians, and express B and R in yards.

Now consider the actual target at T'. (R, you remember, is the measured range, and e is the range error, in yards.)

For the target at T', the rangefinder formula is:

$$\phi = \frac{B}{R + e} \qquad (2)$$

(ϕ is expressed in radians.) Now, if we subtract equation (2) from equation (1) we get:

$$\theta - \phi = \frac{B}{R} - \frac{B}{R + e} \qquad (3)$$

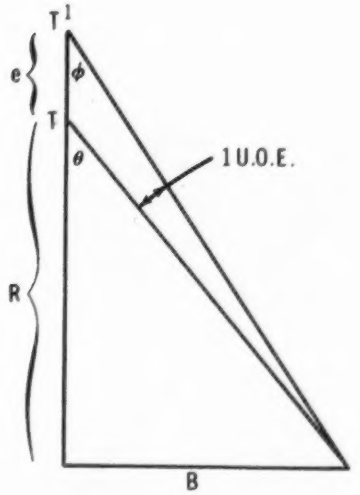


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Figure 6-4.—Diagram to develop the unit-of-error formula.

Simplifying the expression on the right:

$$\theta - \phi = \frac{Be}{R(R + e)} \qquad (4)$$

And, since e is always small compared with R, we can say with sufficient accuracy that:

$$\theta - \phi = \frac{Be}{R^2}$$

Remember that in figure 6-4, we assumed that the operator had made the maximum theoretical error (12 seconds) in measuring the parallactic angle θ. Then ϕ is 12 seconds less than θ, and:

$$\theta - \phi = 12''$$

We cannot substitute 12 seconds in equation (3) because, you remember, θ and ϕ are both expressed in radians. But we can make the substitution if we first convert 12 seconds to radians. (Divide it by 206,265—the number of seconds in one radian.) Then, making the substitution, we have:

$$\frac{12}{206,265} = \frac{eB}{R^2}$$

Now, if you perform the division on the left side of the equation and then solve for e, you have:

$$e = \frac{0.0000582 \text{ X } R^2}{B}$$

The expression on the right is a fraction; you can multiply both numerator and denominator of any fraction by the same number without changing its value. So multiply both parts of the fraction by a million. Then:

$$e = \frac{58.2 \text{ X } R^2}{B \text{ X } 1,000,000}$$

$$e = \frac{58.2}{B} \text{ X } \frac{R^2}{1,000,000}$$

$$e = \frac{58.2}{B} \text{ X} \left(\frac{R}{1,000}\right)^2$$

And there you have the unit-of-error formula for a rangefinder with a magnification of one. A magnification of 2 X will double the apparent parallactic angle, and therefore cut the error in half; a magnification of 3 X will triple the apparent parallactic angle, and therefore cut the error to one third; etc. For large angles that approximation would be way off; for very small angles, such as the parallactic angle of a rangefinder target, it is almost exactly true. So, since the error is inversely proportional to the magnification, we can put M directly in the denominator of the formula. Then:

$$e = \frac{58.2}{BM} \text{ X} \left(\frac{R}{1,000}\right)^2$$

There is the formula for unit of error, arrived at by a series of approximations. But the error caused by those approximations is so small, compared to the range error, that we can ignore it. And that formula works for all Navy rangefinders, both stereoscopic and coincidence.

Now we can make a couple of conclusions about the theoretical accuracy of rangefinders:

1. The precision increases proportionately as you increase the base length and the magnification.
2. The precision decreases proportionately as the square of the range. This means that you can expect four times the error if you double the range.

But do not forget that these conclusions are only theoretical. They represent the best performance we can expect from any rangefinder. Its precision in actual practice will be influenced by many things, including visibility, vibration, target contrast, heat waves, and, of course, the skill of the operator. Only under the most favorable conditions can the precision of a rangefinder approach its theoretical value.

RANGEFINDER CALIBRATION

Complete and accurate calibration data for each rangefinder in service is essential. Correct gun elevation depends primarily on correct measurement of the target range. If the rangefinder readings are inaccurate, the initial salvos will be off in both range and deflection (since drift varies with range). Subsequent analyses of firings may lead to erroneous or conflicting conclusions. Before we can rely on a rangefinder for accurate measurements, we must calibrate it by comparing its readings with other measurements of known accuracy. (The internal adjustment cannot serve the purpose of a complete calibration, since it checks the range scale at only one specified range.)

Although rangefinders are calibrated at assembly, and after each overhaul, their calibration should be checked at every opportunity. Errors can develop from two sources: (1) a slight shift of the end windows (this is rather rare), or of the optical parts of the internal adjuster system or the main optical system; (2) characteristic personal errors of individual operators.

To correct for the constant errors (range error and U.O.E.) we find in a rangefinder, we determine an appropriate offset of the correction scale (called "calibration offset" or "index correction"), and apply it to the correction scale after the internal adjustment. We can make a preliminary calibration of the rangefinder by adjusting its end windows; fine calibration for each individual operator must be made by applying his calibration offset to the correction scale. But when you find that all the operators of a particular rangefinder require fairly large calibration offsets in the same direction, it is a good idea to readjust the end windows.

Whenever you make repairs that involve any major optical part between the end windows and the reticles of a stereo rangefinder, or between the end windows and coincidence prism of a coincidence rangefinder, the instrument should be completely recalibrated.

If the rangefinder is properly adjusted, a single calibration offset (for one particular operator) will be good at all ranges. Under certain atmospheric conditions you may get long or short readings at different ranges; but these effects are mostly small, and they are too elusive to be considered in practice. If a rangefinder has two magnifications, you can use the same calibration offset for both. But always use the highest magnification when you are calibrating the instrument.

When you calibrate a rangefinder, keep these points in mind:

1. Rangefinder errors increase as the square of the range. For that reason, calibration errors that appear insignificant at short range will become serious at long range.
2. When you calibrate a rangefinder against a known range, the probable error of the known range must be considerably less than the probable error of the rangefinder. If the known range has been measured from some point other than the rangefinder you are calibrating, do not forget to apply a suitable correction.
3. Besides the theoretical error, practical considerations limit the accuracy of the rangefinder: heat waves, range rate, vibration, variations in target contrast, etc.
4. Rangefinders are more accurate at high magnification. An instrument with a choice of magnification should be calibrated at its highest power.
5. After a sudden change in temperature, wait several hours before you begin calibration. When you are going to calibrate a turret rangefinder, turn on the turret blowers several hours ahead of time.
6. Variations in the density of the gas inside the instrument (called STRATIFICATION) will cause some inaccuracy when ranging on overhead targets. (This effect is very small when helium is used as the charging gas.)
7. Because of the limitations of lens design, rangefinders are more accurate at the center of the field than at its edges.

CALIBRATION ON MOVING TARGETS

Calibration on moving targets is the method most often used to calibrate a rangefinder against radar. It is suitable for air, surface, or shore targets.

Although rangefinder errors vary as the square of the range, radar error is constant at all ranges. At long ranges a properly calibrated radar is far more accurate than the rangefinder, and we can therefore use it as a standard for calibration. But do not forget that rangefinder errors become very small at short range. At short range a normal internal adjustment provides a more accurate calibration than a check against radar.

On some ships, differential synchros are wired to the radar and rangefinder, and indicate directly the difference in the readings of the two instruments. If this system is not available, you will have to record a series of radar and rangefinder ranges simultaneously. Figure 6-5 shows a form that might be used for this purpose.

The procedure for calibrating a rangefinder against radar on a moving target is as follows:

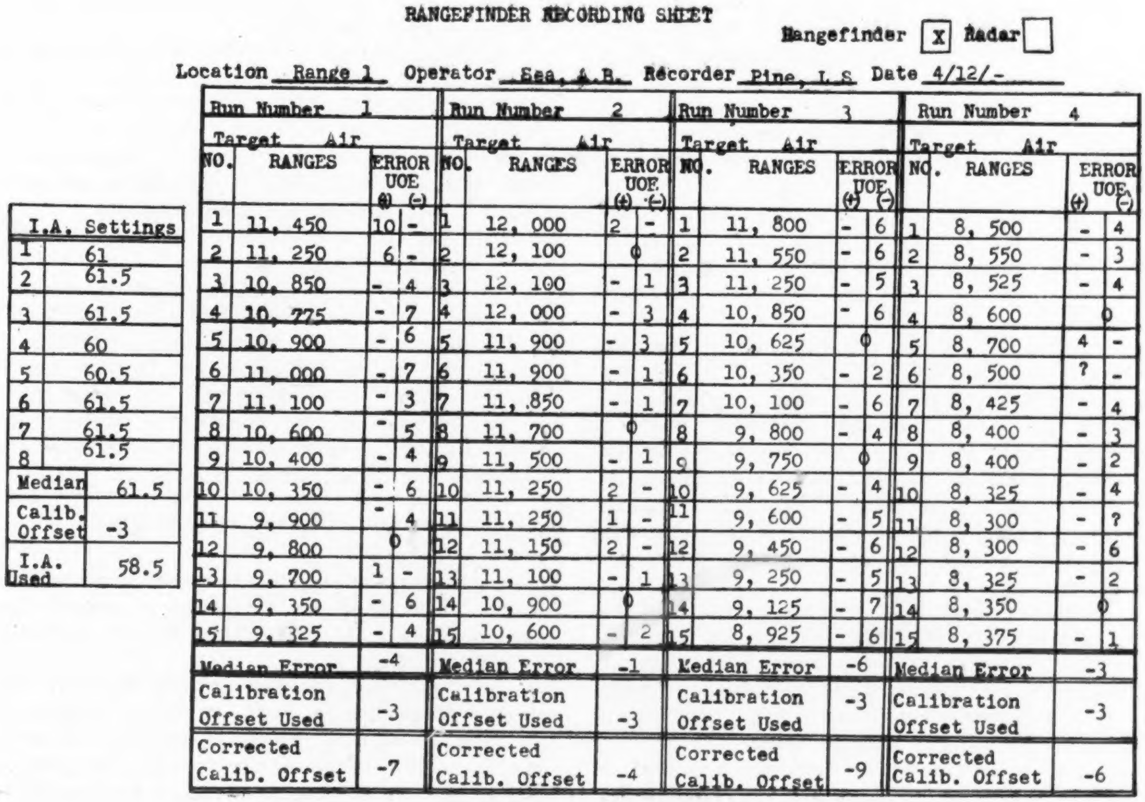
1. Unless the two instruments are in the same station, or connected by a differential synchro, connect them by telephone.

2. Carefully make all the preliminary adjustments of both rangefinder and radar.

3. Record your internal adjustment settings on the recording sheet, and find the median setting. In the rangefinder calibration log find the calibration offset that seems most suitable under the existing conditions. If it is plus, add it to (or if it is minus, subtract it from) the median internal adjustment. Set the correction on the correction scale of the rangefinder, and enter it on the recording sheet in the space marked "I.A. Used."

4. Track a single moving target simultaneously with rangefinder and radar. The radar operator tracks continuously; the rangefinder operator indicates by buzzer when he is "on target." Record both the rangefinder and the radar ranges whenever the buzzer sounds. Use a separate recording sheet for each instrument; label each sheet with the correct instrument name.

5. Record at least 9 readings—and preferably as many as 15—on each run.



RANGEFINDER RECORDING SHEET

Rangefinder ☒ Radar ☐

Location Range 1 Operator Sea, A.B. Recorder Pine, L.S Date 4/12/-

I.A. Settings	
1	61
2	61.5
3	61.5
4	60
5	60.5
6	61.5
7	61.5
8	61.5
Median	61.5
Calib. Offset	-3
I.A. Used	58.5

Run Number 1				Run Number 2				Run Number 3				Run Number 4			
Target Air				Target Air				Target Air				Target Air			
NO.	RANGES	ERROR UOE (+)	(−)	NO.	RANGES	ERROR UOE (+)	(−)	NO.	RANGES	ERROR UOE (+)	(−)	NO.	RANGES	ERROR UOE (+)	(−)
1	11, 450	10	-	1	12, 000	2	-	1	11, 800	-	6	1	8, 500	-	4
2	11, 250	6	-	2	12, 100	0		2	11, 550	-	6	2	8, 550	-	3
3	10, 850	-	4	3	12, 100	-	1	3	11, 250	-	5	3	8, 525	-	4
4	10, 775	-	7	4	12, 000	-	3	4	10, 850	-	6	4	8, 600	0	
5	10, 900	-	6	5	11, 900	-	3	5	10, 625	0		5	8, 700	4	-
6	11, 000	-	7	6	11, 900	-	1	6	10, 350	-	2	6	8, 500	?	-
7	11, 100	-	3	7	11, .850	-	1	7	10, 100	-	6	7	8, 425	-	4
8	10, 600	-	5	8	11, 700	0		8	9, 800	-	4	8	8, 400	-	3
9	10, 400	-	4	9	11, 500	-	1	9	9, 750	0		9	8, 400	-	2
10	10, 350	-	6	10	11, 250	2	-	10	9, 625	-	4	10	8, 325	-	4
11	9, 900	-	4	11	11, 250	1	-	11	9, 600	-	5	11	8, 300	-	?
12	9, 800	0		12	11, 150	2	-	12	9, 450	-	6	12	8, 300	-	6
13	9, 700	1	-	13	11, 100	-	1	13	9, 250	-	5	13	8, 325	-	2
14	9, 350	-	6	14	10, 900	0		14	9, 125	-	7	14	8, 350	0	
15	9, 325	-	4	15	10, 600	-	2	15	8, 925	-	6	15	8, 375	-	1
Median Error		-4		Median Error		-1		Median Error		-6		Median Error		-3	
Calibration Offset Used		-3		Calibration Offset Used		-3		Calibration Offset Used		-3		Calibration Offset Used		-3	
Corrected Calib. Offset		-7		Corrected Calib. Offset		-4		Corrected Calib. Offset		-9		Corrected Calib. Offset		-6	

148.29

Figure 6-5.—Rangefinder recording sheet.

6. Find the error of each rangefinder reading by comparing it with the corresponding radar reading. Convert this difference into units of error, using any of the three methods previously described (the formula, a curve, or the tables in the OP). Record each error on the rangefinder recording sheet; put short errors in the minus column and long errors in the plus column.

7. Find the median of these errors, and enter it on the recording sheet in the space marked "median error." If it is long, mark it plus; if it is short, mark it minus. This figure is the calibration offset. (Be sure you use the MEDIAN, not the mean or average, since occasional wild ranges do not affect the median. To find it: check off the highest error, then the lowest, then the next highest, etc., until only one number is left; that is the median.)

8. Add a plus (or subtract if minus) median error to the calibration offset used; the result is the corrected calibration offset. Enter it in the proper space on the record sheet.

9. Enter the result of each run separately on the rangefinder calibration log. (Fig. 6-6 shows a sample log form.) Be sure you enter the CORRECTED CALIBRATION OFFSET—not the MEDIAN ERROR nor the CALIBRATION OFFSET USED.

10. Determine the calibration offset to be used by each operator pending further tests. Consult the rangefinder calibration log for a particular operator, list his corrected calibration offset for each individual run taken on at least three previous calibration days, and find the median. Use results from more than three days if necessary, to include at least nine individual runs; or if you suspect that the results from runs on a particular day may be unreliable.

CALIBRATION ON FIXED TARGETS

The simplest way to calibrate a rangefinder is by calibrating on fixed targets. Range on a fixed target at a known distance. By comparing the scale reading with the known distance, you can determine the rangefinder error at that range.

You can sometimes use radar to range on a radar beacon. Alongside each radar beacon is a visible marker that makes a convenient target for the rangefinder. This method is most useful at long ranges.

The procedure for calibrating on any fixed target is as follows:

1. Make all preliminary adjustments carefully. Make at least five internal adjustments, and record the median correction.

2. Set the range scale at the known range of the fixed target.

3. Range on the target with the correction knob, and record the settings.

4. If the range scale is properly calibrated, there will be no difference between the median of the settings on the fixed target and the median of the settings on the internal target of the rangefinder.

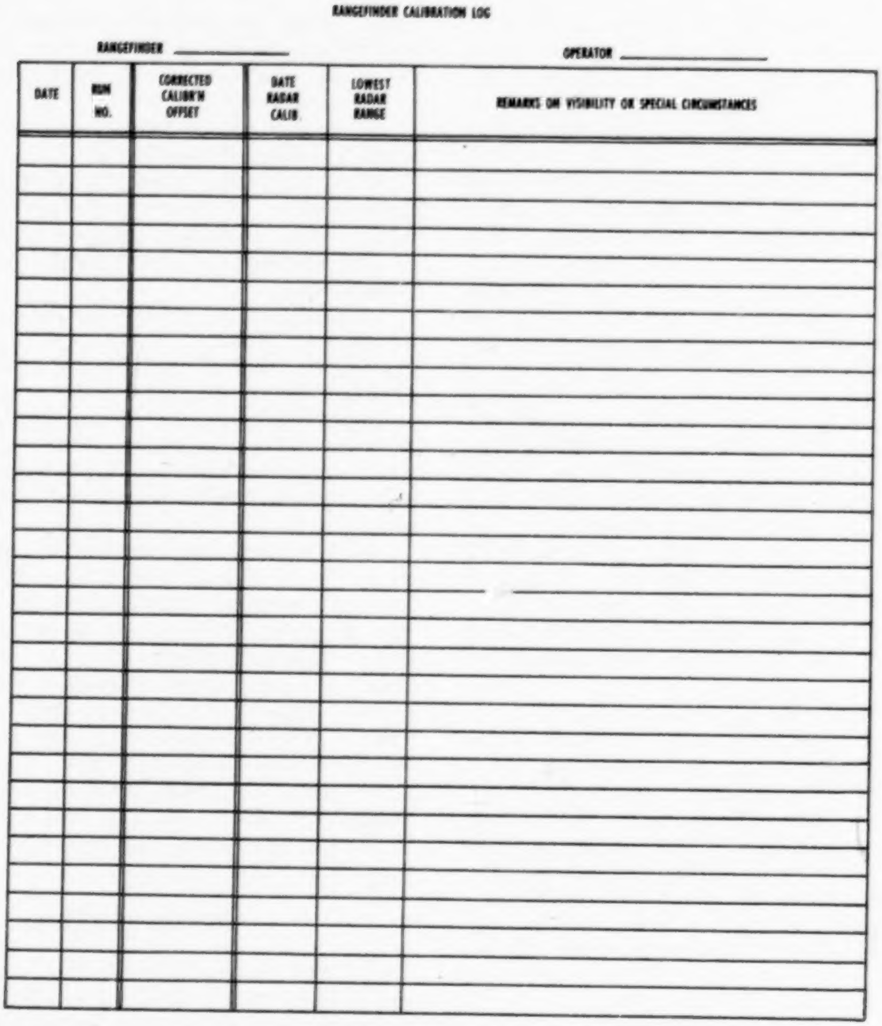
If stationed at a naval shipyard, you should be able to pick out a few easily recognizable objects for use as ranging standards. Use the ground plan of the yard to determine the distance of those objects from the optical shop. If stationed on a repair ship, you will find fixed markers suitable for ranging. If not, ask your department head about setting up some markers.

If necessary you can use the sun, the moon, or a star as a fixed target, by setting the range scale at infinity. You can use the moon either day or night; you can use the sun if the rangefinder has searchlight filters. If you use a star, you will have to make a very accurate height adjustment. This method is useful only when observing conditions are good, and the operators are thoroughly experienced. Experiments show that when inexperienced operators range on an infinity target, they get about three times the spread of readings that they get on targets at a finite distance.

RECORDKEEPING

Calibration results are likely to vary from day to day. To get a reliable calibration offset, the operator should calibrate his rangefinder at every opportunity, and determine the median offset from several days' readings. Using the median of several days' results will tend to nullify the effect of errors made on any one day.

To get the full benefit of rangefinder calibration, the operator must keep accurate records, and apply the results systematically. These records are valuable not only for calibration, but for determining the relative skill of operators as well. By comparing the unit of error spread on the individual recording sheets of various operators, you can get an idea of



RANGEFINDER CALIBRATION LOG

RANGEFINDER ______________ OPERATOR ______________

DATE	RUN NO.	CORRECTED CALIBR'N OFFSET	DATE RADAR CALIB.	LOWEST RADAR RANGE	REMARKS ON VISIBILITY OR SPECIAL CIRCUMSTANCES

148.30

Figure 6-6.—Rangefinder calibration log sheet.

their relative proficiency: the smaller the spread or scatter, the better the operator.

RANGEFINDER MAINTENANCE

Because of its size, a rangefinder looks like a rugged piece of gear. But you know it is a delicate instrument that must be handled with care. When you overhaul it, you will align the elements within extremely small tolerances. It will take careful handling of the rangefinder to preserve your delicate adjustments. No one should be permitted to touch a rangefinder except the qualified operators and the qualified opticalmen.

So that the operator will handle his instrument gently, be sure that all the knobs and levers can be turned smoothly, without jerking or forcing. The internal parts of the instrument normally require no lubrication, except during a

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complete overhaul. To keep oil and oil vapor from reaching the lenses, apply lubricant very sparingly to the parts that extend into the rangefinder. Check the rangefinder mounts regularly and frequently, and lubricate them whenever necessary.

As much as possible, protect the rangefinder from bad weather. Put canvas boots or metal covers over the end boxes of turret rangefinders and over the whole body of exposed instruments, to protect them from rain and spray. If a rangefinder is unavoidably or accidentally exposed to rain or spray, clean it thoroughly and promptly. Take off the covers in good weather to keep moisture from condensing inside them. But protect the optical elements from direct sunlight; it ages the glass and cement, and introduces temporary inaccuracy because of unequal heating.

Clean a rangefinder the same way you would clean a big telescope. Wipe the body with a clean, dry cloth. Gently remove any grit or salt from the outside optical surfaces with a clean camel hair brush. Finally, polish the surfaces with lens tissue. If there is grease on the surfaces, add a drop or two of alcohol to the tissue.

Thoroughly experienced rangefinder personnel will be able to find the cause of any minor difficulty, and correct it. But the less experienced operators will probably call on you for help. Here is a list of minor rangefinder troubles; you should be able to recognize them and correct them without hesitation:

1. Bulbs loose, burned out, or in wrong receptacles.
2. Rheostat turned too low.
3. Range scale set at wrong range during internal adjustment.
4. Adjuster knob turned only partly into position.
5. Reticle lights on when making internal adjustment.
6. Change-of-magnification knob between two positions.
7. Color filters part way in.
8. Neutral of polaroid filter unintentionally turned in.
9. Height adjustment incorrect.
10. Astigmatizers unintentionally turned in.
11. Searchlight filter in.

DRYING AND CHARGING THE RANGEFINDER

Rangefinders are charged with dry gas, under about two pounds pressure. The primary purpose of charging is to keep moisture from condensing on the optical surfaces; the secondary purpose is to protect the optical elements from the aging effect of oxygen. In charging the rangefinder you pass compressed gas from a cylinder, through a pressure-reducing valve and a dryer, into the instrument. Before the final charging, dry the instrument thoroughly, either by flushing it with dry gas or by repeatedly drawing a vacuum of about 22 inches.

The Navy uses two different gases for rangefinder charging: nitrogen and helium. Nitrogen has one marked disadvantage: it tends to stratify into layers of different indices of refraction. When you elevate the instrument to range on aircraft, light rays will be refracted in passing from one layer of nitrogen to another, thus causing a small error in range setting. For this reason, antiaircraft rangefinders are always charged with helium, which has much less tendency to stratify.

But because its molecules are considerably smaller than those of nitrogen, helium has a greater tendency to leak. The gas purity of helium-filled instruments should be checked every two weeks. You can use a special helium-purity gage for this purpose. If the gage is not available, you can check the helium purity by making two internal adjustments—one when the rangefinder is level and one when it is elevated 90°. There will always be a difference between the two settings. But if you make the check every two weeks, and find that the difference suddenly increases, you can assume that the helium is no longer pure.

Some instruments are designed for helium, others for nitrogen. Always charge an instrument with the gas it is designed for. Helium and nitrogen have different indices of refraction. You know that refraction in an optical element depends on the ratio of its index of refraction to that of the surrounding atmosphere. If you put one gas in an instrument designed for another, you will change the optical characteristics of the whole system. On instruments designed for HELIUM, the charging nipples are always painted ORANGE or YELLOW.

Optical instruments should be recharged every 12 months with dry gas. It is much harder to dry out a damp instrument than it is to keep moisture from condensing in the first place. Follow these rules:

1. Recharge optical instruments before the conclusion of each overhaul of a ship alongside a repair ship or tender, or at a shipyard.
2. Recharge each instrument at intervals of 12 months whether or not it appears to need recharging.
3. When an instrument shows any sign of condensation on an internal surface, RECHARGE IT AT ONCE.

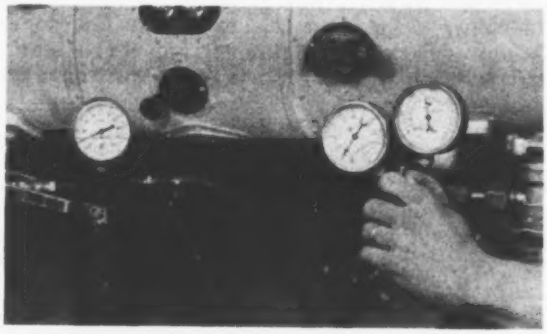
Use an Optical Instrument Dryer of the portable type. (This dryer is improperly named; actually, it is a gas dryer, not an instrument dryer.) The dryer contains a quantity of silica gel, which absorbs moisture from the gas passing through it. A part of the silica gel has been impregnated with cobalt chloride, which serves as a moisture indicator. When the indicator begins to turn pink, take the gel out of the dryer, and bake the moisture out of it in an oven. Then return it to the dryer for further use.

Here are three important precautions to remember about drying and charging:

1. Do not use any cylinder gas to charge an optical instrument if the pressure in the cylinder has fallen below 400 pounds per square inch.
2. Instrument drying is most effective at high temperatures. Never try to dry an instrument when the temperature is below freezing.
3. To ensure complete drying, repeat the exhausting and charging cycle several times.

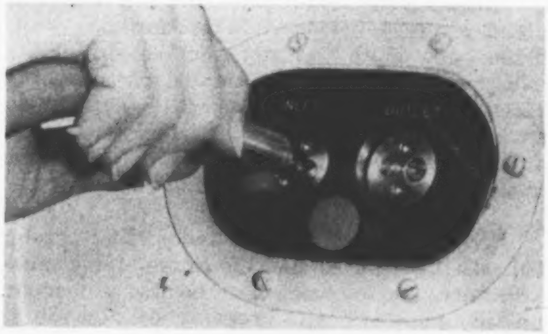
Here are the steps to follow in drying and charging the Rangefinder MK 42:

1. Attach the regulator valve to the helium cylinder, using a left-hand thread adapter.
2. Connect the short hose to the outlet side of the dryer. Use the long hose to connect the inlet side of the dryer to the regulator valve on the cylinder.
3. Open the cylinder valve. Set the regulator valve between 7 and 10 pounds pressure. (See fig. 6-7.) Run a small quantity of gas through hoses to be sure they are dry. Then close the cylinder valve.
4. Remove the inlet-valve plug from the rangefinder, and connect the short hose to the inlet. (See fig. 6-8.)
5. Open the cylinder valve and build up 5 pounds pressure in the rangefinder. This is the maximum safe pressure you can put in a rangefinder. While you maintain this pressure, use a liquid soap solution to test all plates and connections for leaks. (See fig. 6-9.)



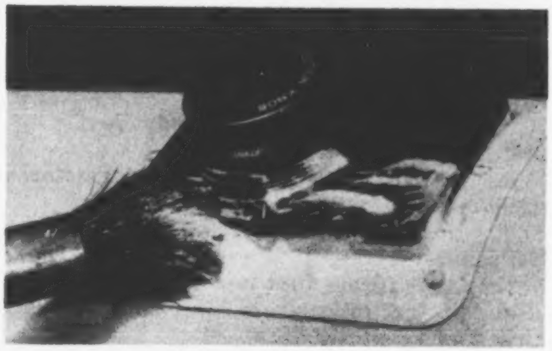
148.31

Figure 6-7.—Setting the regulator valve.



148.32

Figure 6-8.—Connecting the hose to the inlet.



148.33

Figure 6-9.—Testing for leaks.

6. Attach the hose of the helium-purity indicator to the outlet valve of the rangefinder, and adjust the mechanical and electrical zeros of the indicator. Open the cylinder valve.

7. Run helium, at 5 pounds pressure, through the rangefinder and the helium-purity indicator. (See fig. 6-10.)

8. When the helium-purity indicator shows 97.5 percent helium by volume, close the valves and disconnect the dryer from the rangefinder.

RANGEFINDER INSPECTION

Rangefinders must be inspected regularly to keep defects from developing unnoticed. The operator should check these items frequently.

1. Cleanliness of exposed optical surfaces.
2. Supply of lens tissue at the rangefinder station.
3. Cleanliness of eye guards.
4. Lubrication of mount.
5. Helium purity (in antiaircraft rangefinders).

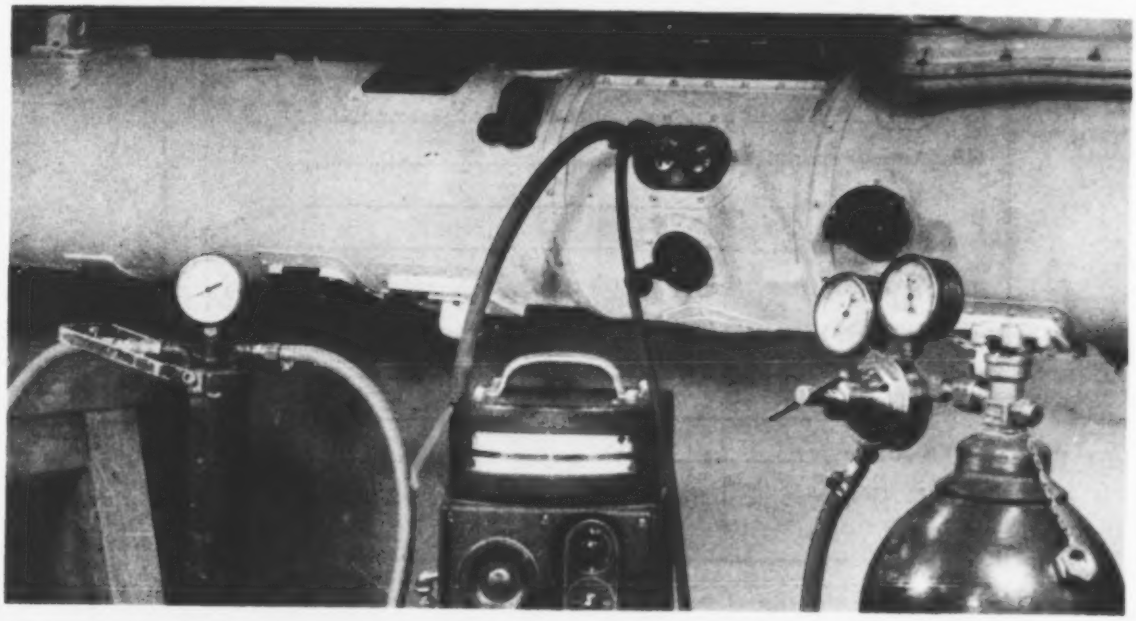
The Opticalman should make a complete inspection every 3 months, and immediately after the rangefinder has been subjected to rough treatment—for example, prolonged main-battery firing.

STEREOSCOPIC RANGEFINDER INSPECTION

The checklist in figure 6-11 might be used in your inspection of the stereoscopic rangefinder. But do not let the checklist limit your inspection—a list made up beforehand cannot include every possible condition. Record all pertinent information, whether or not you have made a space for it on your checklist.

CLARITY OF SCALES.—The scales must be clean and readable. The internal and external range scales are especially important; the two must read the same within one unit of error. If they do not, look for lost motion in the range-knob linkage.

CLARITY OF IMAGES.—Check the definition in both fields. At the best possible focus, both reticle patterns and both target images should be equally clear. In every telescope system the image will be sharper in the center of the field than at its edges. But if the image is



148.34

Figure 6-10.—Running helium through the rangefinder and the purity indicator.

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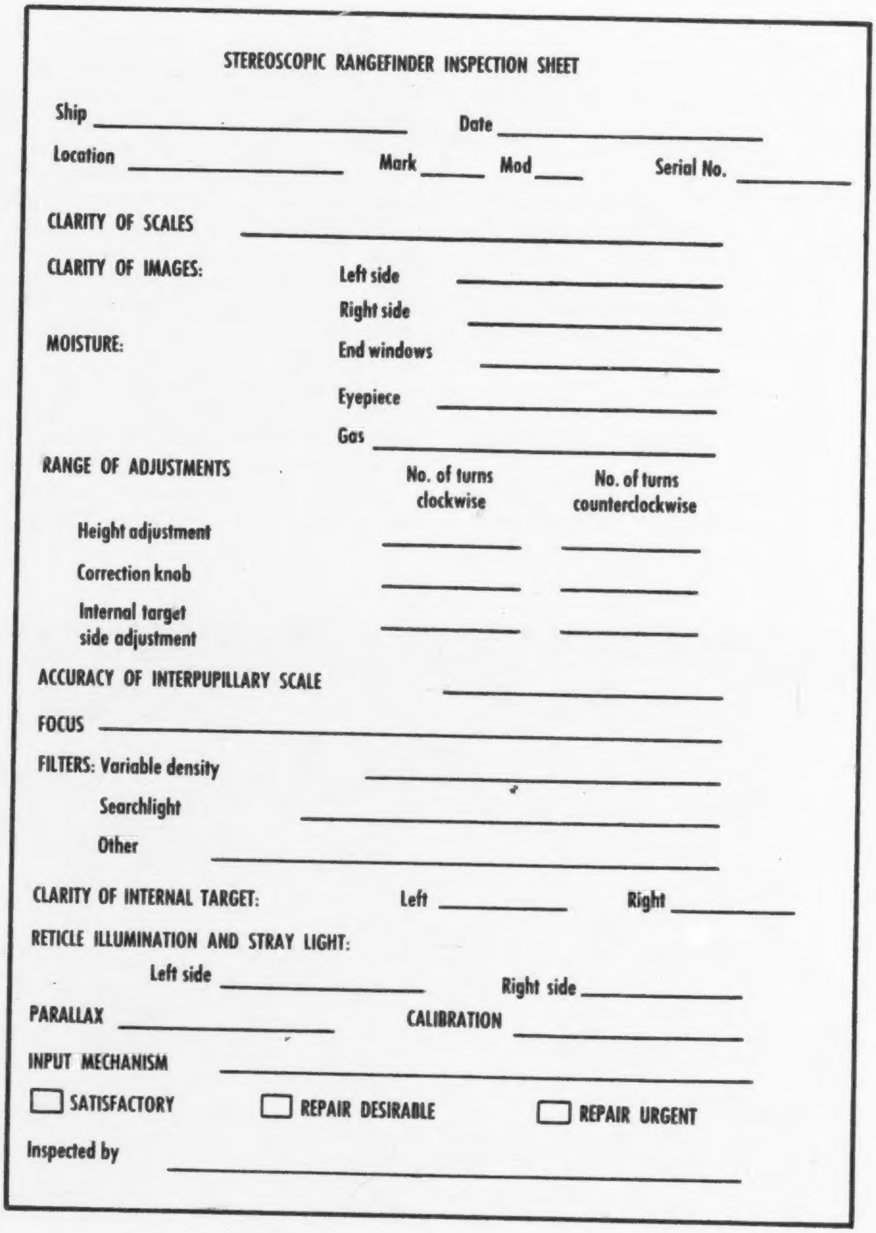


STEREOSCOPIC RANGEFINDER INSPECTION SHEET

Ship ____________ Date ____________

Location ____________ Mark ____ Mod ____ Serial No. ____________

CLARITY OF SCALES ____________

CLARITY OF IMAGES: Left side ____________

Right side ____________

MOISTURE: End windows ____________

Eyepiece ____________

Gas ____________

RANGE OF ADJUSTMENTS

	No. of turns clockwise	No. of turns counterclockwise
Height adjustment	____	____
Correction knob	____	____
Internal target side adjustment	____	____

ACCURACY OF INTERPUPILLARY SCALE ____________

FOCUS ____________

FILTERS: Variable density ____________

Searchlight ____________

Other ____________

CLARITY OF INTERNAL TARGET: Left ____________ Right ____________

RETICLE ILLUMINATION AND STRAY LIGHT:

Left side ____________ Right side ____________

PARALLAX ____________ CALIBRATION ____________

INPUT MECHANISM ____________

☐ SATISFACTORY ☐ REPAIR DESIRABLE ☐ REPAIR URGENT

Inspected by ____________

148.35

Figure 6-11.—Inspection sheet.

sharper in one of the rangefinder telescopes than it is in the other, you can be sure there is a shifted element or a dirty surface somewhere in the optical system. Look through the end windows for dust, smudges, and moisture.

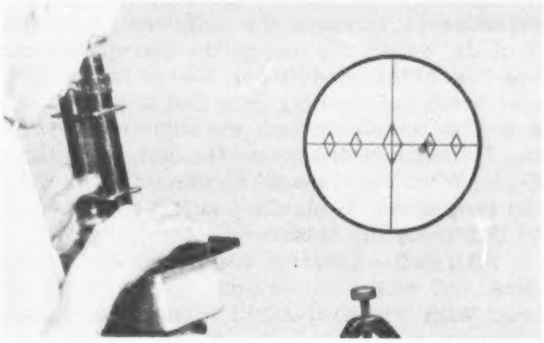
MOISTURE.—If there is condensed moisture on one of the inner optical surfaces, you can often see it by looking through the end window. If you see any sign of condensation, dry and recharge the rangefinder promptly. (Do not forget to look for moisture in the eyepiece assembly, which is often outside the gas seal.) Even if there is no sign of moisture, check the date on which the instrument was last charged, to see if it is time for recharging.

DIPVERGENCE.—Dipvergence is sometimes called UP-AND-DOWN DIVERGENCE, or STEP. In a properly aligned rangefinder, the rays emerging from the two eyepieces are parallel, or nearly so. If they are not, the operator will suffer from eyestrain; in extreme cases he will not be able to fuse the two images. To test for dipvergence elevate the rangefinder toward clear sky, so that you see nothing but the reticle pattern. Hold your head about 6 inches from the eyepieces. Look at the center reticle marks, and break their stereoscopic fusion as you do when checking the height adjustment. The two marks should appear to be at the same height, with an allowable error of one fourth the height.

The dipvergence test is easier if you have a comparator; set it over the eyepieces, as in figure 6-12. The allowable error is 30 minutes in divergence and 10 minutes in height. To bring the error within tolerance, align the eyepiece prisms by moving their adjustable locking bolts, as in figure 6-13.

RANGE OF ADJUSTMENTS.—Check the limits of the various adjustments. In each, the correct adjustment should fall within the middle third of the total available motion. (At extreme temperatures the correction scale may read outside these limits.) If there is no scale on the adjustment, count the number of turns available between the correct setting and each of the two stops. Check the adjustment mechanism for erratic action; there should be no catching or binding, and no lost motion.

Adjust the interpupillary distance (IPD) scale during each overhaul. During the inspection, check for lost motion between the eyepieces and the scale pointer. If there is no lost motion, it can usually be assumed that the adjustment is still correct. Set the scale and the focus; look through the eyepieces, pressing your face fairly hard against the eyeshields. Check the focus and IPD scales again, to be sure they have not changed.

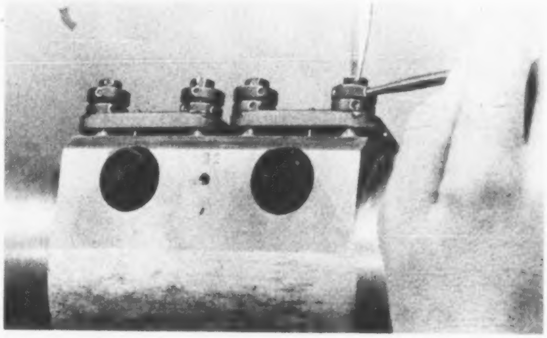


148.36

Figure 6-12.—Using the comparator to test for dipvergence.

FOCUS.—Set the rangefinder at its highest power, and set the two diopter scales at zero. Use an auxiliary telescope to look through the eyepieces and focus the auxiliary telescope to give a sharp image of the target and reticle. Now shift to low power. The target and reticles should still be in sharp focus, without resetting either the auxiliary telescope or the diopter scale of the rangefinder.

MAGNIFICATION.—Use a dynameter to check the exit pupil, the eye distance, and the magnification on each side of the instrument as shown in part A of figure 6-14. (When checking



148.37

Figure 6-13.—Adjusting the eyepiece prisms.

for equal magnification during an overhaul in the optical shop, put an aperture stop over the objective to increase the definition, as in part B of fig. 6-14.) To change the magnification on one side of the rangefinder, loosen the setscrew that holds the erecting-lens cell in place. With a scribe, reach through the adjustment hole in the optical bar and rotate the cell, as in figure 6-15. When equal magnification on both sides of the rangefinder is obtained lock the cell in place by tightening the setscrew.

FILTERS.—Examine the filters for cleanliness and ease of operation. Then make this test: With the clear filter in the line of sight, range on a fixed target and make stereoscopic contact. Then throw the filters in, one at a time. None of the filters should break stereoscopic contact with the fixed target. If one of them does, you will know that the filter's surfaces are not parallel; replace it with a new filter.

INTERNAL TARGET.—The central portion of the internal target should be sharply defined and well illuminated—in other words, easy to range on.

ILLUMINATION.—Make this test at night; a daytime check will give unsatifactory results. The illumination of the two reticles should be approximately the same. There should be a minimum of stray light and ghost images in the system. If you see stray light in the instrument, remove one bulb at a time until you find the one that is causing the trouble. You can sometimes remove ghost images or stray light simply by adjusting a bulb in its housing.

PARALLAX.—Range on a fixed target at a distance of 2,000 yards or more, and use an auxiliary telescope to check for parallax on each side of the rangefinder. If necessary, unlock the objective cell and adjust it to remove parallax (fig. 6-16).

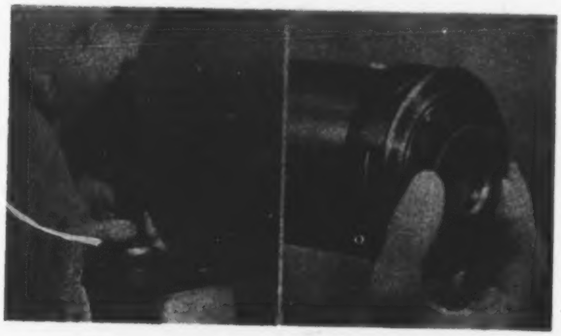
CALIBRATION.—Check the calibration on the longest available known range, then at short range, and finally at an intermediate range.

INPUT MECHANISM.—Rangefinders equipped with input and output mechanisms must be tested electrically. The two synchro units must be set to electrical zero when the range reads 10,000 yards.

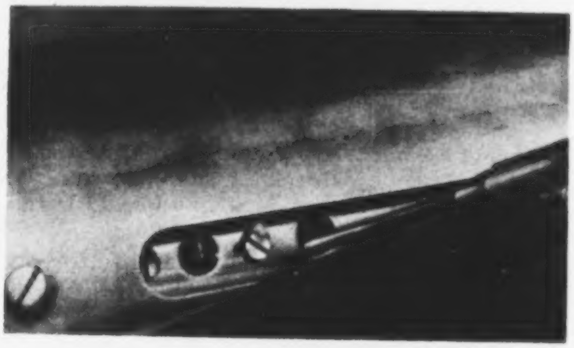
SHOCK TESTING.—When you make a test that might be influenced by mechanical shock—the internal adjustment, for example—strike each of the rangefinder bearings with a soft hammer, at each of four points 90° apart. Then repeat the test. If the results are significantly different, they may indicate that one or more of the internal elements is loose in its mounting.

FINDER'S TELESCOPE.—Check to see that the target image, when it is centered in the rangefinder field, is also centered in the finder's telescope. In the finder's telescope the target image, the crosslines or circle, and the inside scale, should all be in focus at the same diopter setting.

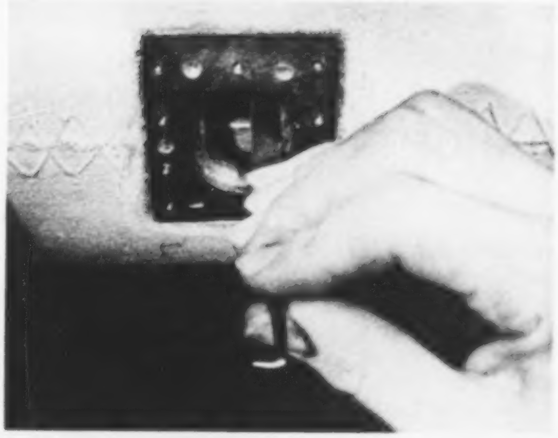
Bear in mind that all these inspection tests are intended only to supplement the calibration exercises—not to substitute for them. Some maladjustments of the rangefinder are so elusive that it takes a complete overhaul to find them. But they show up as a history of bad ranging and erratic internal adjustment settings. When the record shows sudden large changes in the correction settings, you can be fairly sure that trouble is developing.



148.38
Figure 6-14.—Checking magnification with a dynameter.



148.39
Figure 6-15.—Rotating the erecting-lens cell.



148.40
Figure 6-16.—Adjusting the objective.

Rangefinder operators will make only the simple adjustments; casualty analysis is your job. It is up to you to decide, on the basis of your inspections and the calibration logs, when serious trouble exists, and what should be done about it.

COINCIDENCE RANGEFINDER INSPECTION

With a few obvious exceptions, such as interpupillary distance setting, the inspection tests just described will apply equally well to the coincidence rangefinder. Here are a few more tests, which apply to the coincidence type only:

ASTIGMATIZERS.—With the astigmatizers out, range on a slender, vertical target that makes good contrast against its background. Then range on the same target with the astigmatizers in. The two readings should be the same.

HALVING.—Turn the halving adjuster knob through its entire travel, and count the turns. Then turn back half way. The instrument should be approximately in the halving position. Roll the rangefinder in its bearings, and then recheck the halving adjustment.

LEAN.—Range on a target at the right-hand side of the field, and make a careful halving adjustment. Swing the rangefinder in azimuth to bring the target to the left-hand side of the field. The halving adjustment should still be correct.

COMPENSATOR SETTING.—Range on a target near the minimum range, and make a careful halving adjustment. Then range on a target near the maximum range. The halving adjustment should remain correct. (You need not know the true range of the two targets.)

LEAN IN THE INTERNAL ADJUSTER TARGET.—Range on the I.A. target, and then turn the halving adjustment until the target is almost hidden under the halving line. Make 10 internal adjustment readings at this setting, and find the median. Rotate the halving adjustment until the halving line covers only a small part of the target. Make 10 internal adjustments at this setting, and find the median. The two median readings should be the same, within one unit of error.

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CHAPTER 7

STEREOSCOPIC RANGEFINDER

This chapter describes the disassembly, reassembly, and collimation of the stereoscopic rangefinder Mark 42 Mod 27. A detailed discussion of one particular instrument is used to illustrate the repair of a whole class of instruments. After you have mastered one Mark of rangefinder, and gained practical experience in the shop, the information provided by Ordnance Pamphlets and drawings will enable you to repair any rangefinder.

The first major section of this chapter will describe the principal components of the rangefinder Mark 42 Mod 27. The second major section will be on the complete disassembly, reassembly, and collimation of the rangefinder.

DESCRIPTION OF RANGEFINDER MARK 42

Rangefinder Mark 42 and all Mods are of the stereoscopic, wandermark type, with change-of-magnification input mechanism. The only difference between the various modifications of the Mark 42 lies in the general arrangement of certain units. The function of any given unit is the same in all modifications. Figure 7-1 shows a cross-sectional view of the Mark 42 Mod 27 rangefinder.

The main structural elements consist of three tubes: The inner and outer tubes which form a double-walled main tube, and an optical bar (tube) mounted inside the inner tube. Locate these three tubes in figure 7-1.

END REFLECTORS

It is essential in a rangefinder that the rays of incidence to the finder be reflected at fixed angles in the instrument; this is the function of the end reflectors. If a single prism or mirror with total reflection is used at each end, and either is turned in the plane of triangulation, the angle reflected will not remain a constant. To avoid this difficulty, the end reflectors used in the rangefinder are of the pentagonal prism type, shown in figure 7-2. They have two reflecting surfaces. With this type reflector, if the angle between reflectors is 45°, they always reflect at an angle of 90°, even when rotated. The right end reflector, however, does not reflect an angle of 90° but is constructed to reflect a fixed angle of 89° 49′ 6″.

The end reflectors used in the Mark 42 rangefinder are of the built-up type, with two silvered glass mirrors mounted to a steel block. The mirrors used on rangefinders Mark 42 Mods 25, 26, and 27 are front surfaced aluminized mirrors. The mirrors have plane parallel surfaces, and are of sufficient thickness to retain their shape, but are not so thick that changes of temperature will affect them by causing internal distortions. The block is made from a solid piece of steel having an expansion coefficient approximately the same as that of the glass. The mirrors rest on three raised spots which are carefully finished and polished. A steel spring plate with three similar spots holds the mirror firmly to the steel block, yet it is free to expand and contract with temperature changes, without introducing any strain or stress in the reflectors. The underside of each steel block has a three-point bearing, with a ground and lapped finish. The steel blocks are bolted to the brackets fastened to the ends of the inner tube. The only effect of the movement of these reflectors, due to slight deformations of the inner tube, is to throw the images out of adjustment in height, which can be readily corrected by the height adjuster, as will be explained later. Two end reflectors are shown in figure 7-2; one is shown assembled and fastened in position in its mount, while the other is broken down into its component parts.

OBJECTIVES

The functon of the objectives is to form real images of the target on the reticles. The objectives are made and mounted with great precision. If the focus of both objectives is not exactly the same, the magnification of the image seen by the right and left eyes will differ and the range readings will be incorrect. Lack of uniformity in the focus of objectives is readily detected when a target is observed that is not in the center of the field. The right and left objective lenses are therefore selected and adjusted to give the same focus. They are composed of a positive lens of crown glass and a negative lens of flint glass. The objectives are mounted in steel frames and separated by steel spacing rings. The objective mountings and the spacing between them must be carefully adjusted to give the correct focus; the objectives must be held firmly in their mounts without strain.

To disassemble the objective, first unscrew the objective ring, as shown in figure 7-3. Remove the positioning bolt (shown just to the right of the repairman's thumb in fig. 7-3) and slide the objective mount out of the optical tube. Unscrew the two locking rings from the objective cell. Back off the set screw and remove the retaining ring. Slip out the lens elements and spacers. Figure 7-4 shows the two objectives after disassembly.

EYEPIECE PRISMS

The two eyepiece prisms, which reflect the two lines of sight into the eyepiece, are located in the center of the rangefinder. (They are marked No. 27 in fig. 7-1.)

Figure 7-5 shows the two eyepiece prism mounts of the Mk 42 Mod 27 rangefinder. (The repairman has removed the left prism mount, by taking out the two adjustable locking bolts and one screw.)

EYEPIECE ASSEMBLY

Refer back to figure 7-1 to identify the principal parts of the eyepiece assembly: the two rhomboid prisms (No. 28), the color filters (26), and the eyepiece lenses (29). The eyepiece assembly is covered in Opticalman 3 & 2, NavPers 10205; you should already be familiar with the functions of its parts. The rhomboid prisms, with two reflecting surfaces in each, offset the rays without changing their direction or length of travel. By pivoting on an axis through their front surfaces, the two rhomboid prisms provide an interpupillary adjustment.

The two eyepiece lenses have separate focusing mounts, so that each may be adjusted to provide the observer with a sharp image.

The color filters are so mounted that turning a single knob will bring the filters of the same color into each field. In the rangefinder Mk 42 Mod 27 the filters are arranged in this order: red, yellow, clear, and polaroid.

The eyepiece assembly is mounted on the outer tube of the rangefinder. The outer tube is subject to greater changes due to temperature than either of the other tubes. But the position of the eyepiece is somewhat less critical than that of the other optical groups. The eyepiece has no part in the delicate measurements made by the rangefinder—it serves only as a magnifier, to help read those measurements. Since the eyepiece assembly is completely outside the main gas seal of the rangefinder, you can remove and clean it without breaking the seal.

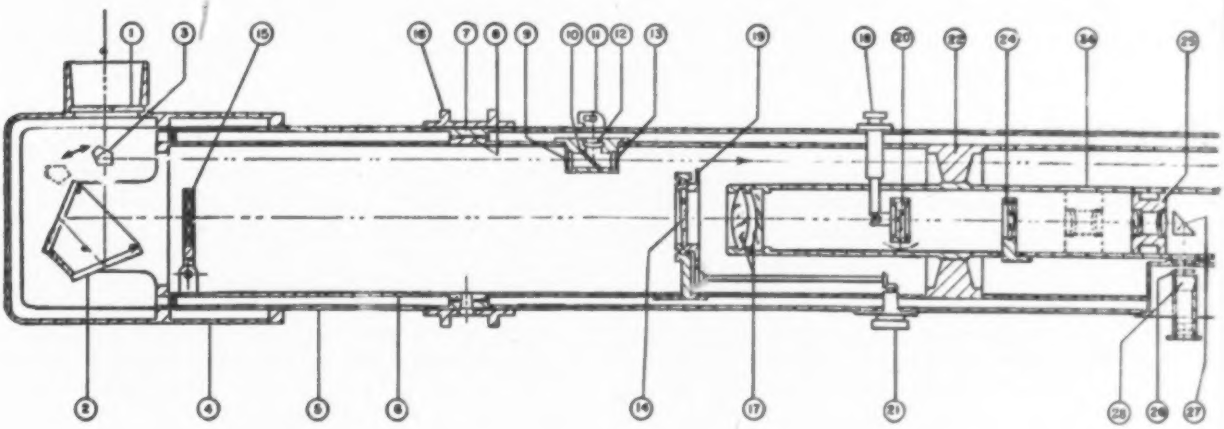
ERECTING LENS SYSTEM

The erecting lens system has three functions: (1) it provides an erect image of the target; (2) it effectively extends the focal plane of the eyepiece to coincide with the focal plane of the objectives at the reticles; and (3) in some rangefinders it provides a means for changing the magnification. In the rangefinder Mk 42, the erecting system provides a choice of either 12 or 24 power.

The erector lenses are mounted in erector slides. The two slides fit into the optical tube; each slide is connected by a bar to the change-of-power disk. The change-of-power lever rotates the disk; as it rotates, the rods move the slides toward or away from the eyepiece prisms. Spring stops hold the disk in either of its two alternate positions.

RETICLES

In assembling a rangefinder, the reticles are fixed in the focal planes of the erectors. The objectives are then moved in or out until their focal plane (on a target at a range of 2,000 yards or more) coincides with the plane of the reticle markings. Each reticle is mounted in a frame; this frame can be rotated about the axis, and can be moved in any direction along the axis. Because the reticle has these two motions, it can be



1. END WINDOW WEDGE
2. END REFLECTOR
3. INTERNAL ADJUSTER PRISM
4. END BOX
5. OUTER TUBE
6. INNER TUBE
7. INNER TUBE SUPPORT
8. INNER TUBE BEARING
9. INTERNAL ADJUSTER ALIGNMENT WEDGE
10. INTERNAL ADJUSTER REFLECTOR
11. INTERNAL ADJUSTER LIGHT
12. INTERNAL ADJUSTER CONDENSING LENS
13. INTERNAL ADJUSTER OBJECTIVE RETICLE
14. INTERNAL ADJUSTER CORRECTION WEDGE
15. SEARCHLIGHT FILTER
16. MAIN BEARING
17. OBJECTIVE LENS

rotated to level its markings, and its center mark can be aligned with the optical axis of the rangefinder. The frame is so mounted that you can remove it without disturbing the other optical parts of the instrument.

Each reticle is a plano-convex lens, with its plane surface toward the objective. The convex surface helps to converge light toward the erector, and thus ensures full illumination of the whole field. The markings are etched on the plane surface; the etched lines are filled with an opaque material, which makes them easier to see. When the reticle illuminator is being used for night ranging, light passes through a lucite rod to the edge of the reticle. The light is then reflected toward the eyepiece from the inner surface of the filled lines.

COMPENSATOR UNIT

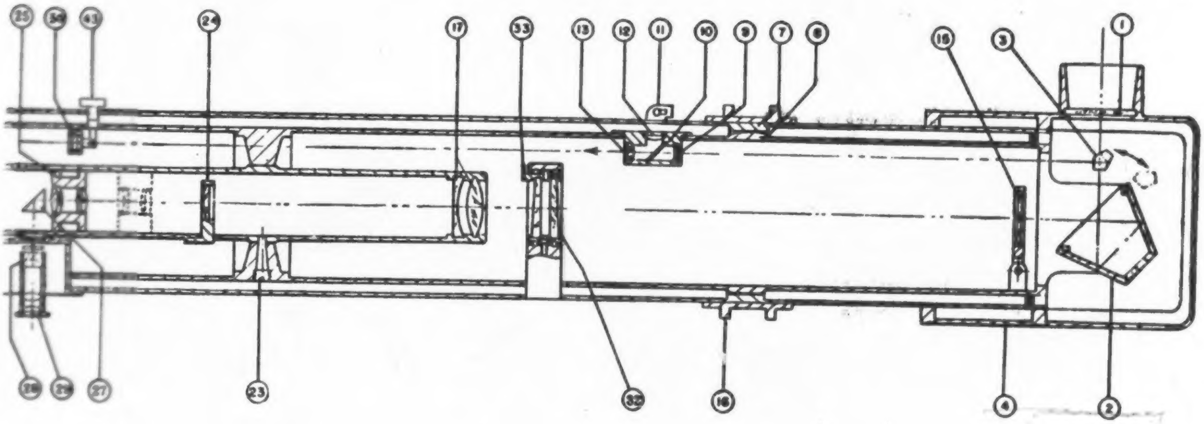
The compensator unit of the Mk 42 is mounted between the right objective and the right end window. It consists of two achromatic wedges, so mounted that you can rotate them about the optical axis. The rotation of the two wedges is equal, and in opposite directions, so there will be no vertical deviation of the image. The wedges are rotated by either the range knob or the change-of-range input mechanism.

There are two range scales. A glass scale (No. 33 in fig. 7-1) is secured to the mount of the two wedges. The telescope for viewing this scale is attached to the outer tube of the rangefinder. This scale reading telescope is located about 2 1/2 feet to the right of the eyepieces; your line of sight through it is parallel to that through the oculars.

The external range scale is located in the change-of-range gear box. The scale can be viewed along a line of sight parallel to that through the oculars; or if a prism is swung into position, the scale can be viewed along an axis at an angle of 45° to that of the oculars.

CHANGE-OF-RANGE INPUT

Mk 42 rangefinders are fitted with a change-of-range input mechanism. When ranging on a



18. HEIGHT ADJUSTMENT KNOB
19. CORRECTION SCALE
20. HEIGHT ADJUSTMENT PLATE
21. INTERNAL ADJUSTER CORRECTION KNOB
22. OPTICAL BAR SUPPORT
23. OPTICAL BAR LOCK STUD
24. RANGEFINDER RETICLE
25. ERECTING LENSES
26. COLOR FILTER
27. EYEPIECE PRISMS
28. EYEPIECE RHOMBOID PRISMS
29. EYE LENSES
30. INTERNAL ADJUSTER TARGET CENTERING PLATE
32. COMPENSATING UNIT
33. INNER RANGE SCALE
34. OPTICAL TUBE
43. INT. ADJUSTER TARGET CENTERING KNOB

148.41

Figure 7-1.—Cross-sectional view of rangefinder Mk 42 Mod 27.

moving target, a computing device introduces the estimated change of range into the range finder. The change of range is introduced by rotation of the input shaft; a range conversion mechanism converts the estimated change into actual rotation of the shaft.

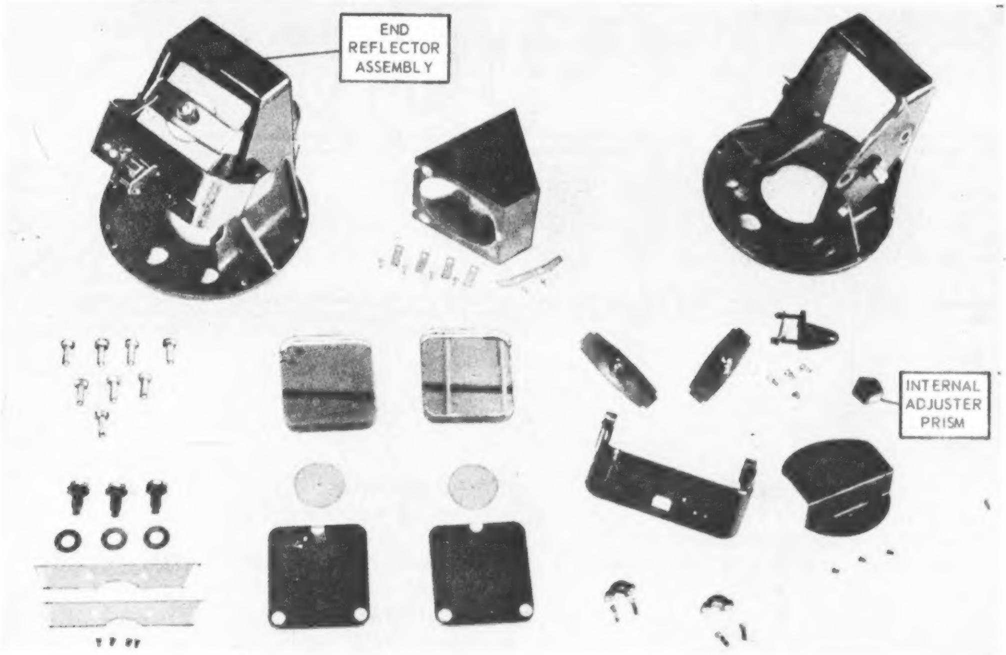
At ranges between 2,000 and 72,000 yards, one revolution of the shaft changes the range setting by 50 yards. Counterclockwise rotation (viewing the shaft from its outer end) increases the range reading; clockwise rotation decreases it. At ranges below 2,000 yards, or above 72,000 yards, one rotation no longer corresponds to a [illegible] yard change in range reading, but will vary depending on how low or how high the range reading is.

The change-of-range mechanism is housed in a gear box, which is mounted on the outer tube of the rangefinder. Figure 7-6 illustrates the arrangement of the shafts, the differential, the cam, and the compensator. A rotation of either the range knob (No 37 in fig. 7-6) or the input shaft (No. 38) will cause rotation of the differential. Motion of the differential will be transmitted to the cam (58); motion of the cam is transmitted through a follower and a sector to the compensator unit (32).

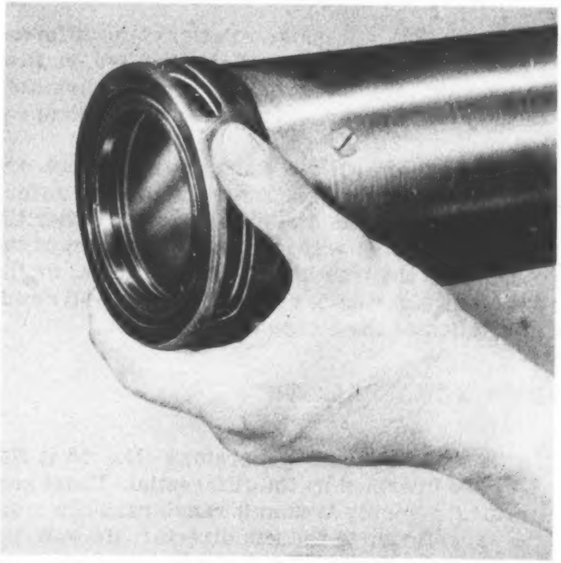
Since the input shaft and the range knob are connected to the compensator unit through differential gears, it is possible to rotate either the shaft or the knob without causing a rotation of the other. But the rotation of either of them, or the simultaneous rotation of both of them, will result in rotation of the compensator wedges.

RANGE TRANSMISSION

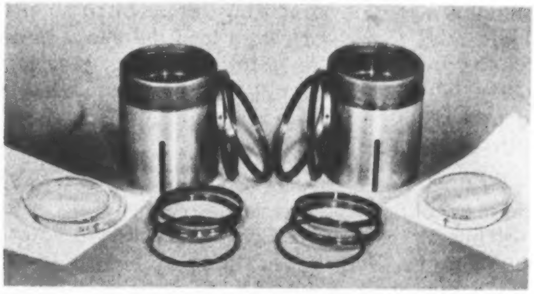
The two synchro generators (No. 56 in fig. 7-6) are operated by the differential. These generators instantly transmit range readings from the rangefinder to the gun director. Between the limits of 2,000 and 72,000 yards, rotation of the generator rotors is directly proportional to the change in range.



148.42
Figure 7-2.—Rangefinder Mk 42 Mod 27 end reflector.



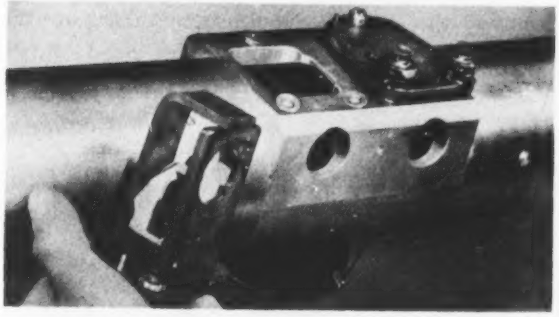
148.43
Figure 7-3.—Removing the objective ring.



148.44
Figure 7-4.—Objective mounts, disassembled.

On the range knob is a spring-actuated push-button, by which the operator can control a light or other signal on the range indicator, to show when the range is to be read.

The height adjuster provides a means for moving the left-hand image up or down to bring it to the same apparent height, in relation to its reticle, as the right-hand image.

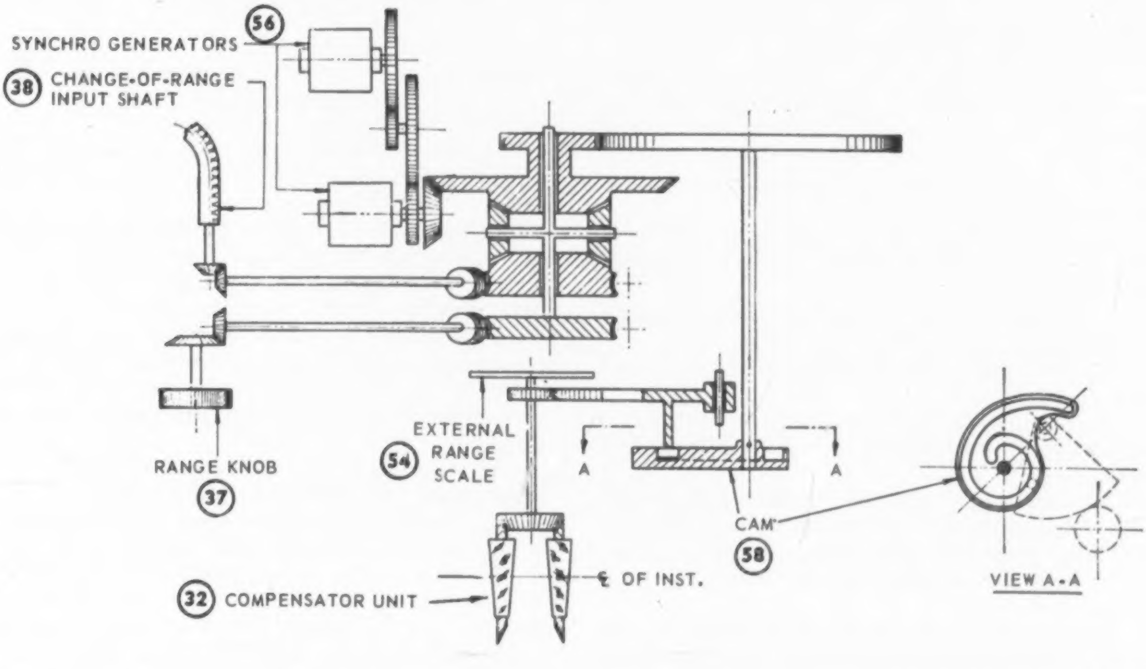


148.45
Figure 7-5.—Removing the left eyepiece prism mount.

CORRECTION WEDGE

The correction wedge, controlled by a knob, rotates about the line of sight on the rangefinder axis. It corrects known errors of the rangefinder, and habitual errors of the individual operator.

The correction scale is secured to the correction wedge mount. An increase in the correction scale reading will cause a decrease in the range scale reading. The telescope for viewing the correction scale is mounted just to the left of the main oculars; the line of sight through it is parallel to that through the oculars.



148.46
Figure 7-6.—Change-of-range mechanism (schematic), rangefinder Mk 42 Mod 27.

The height-adjustment unit is mounted on the inner tube of the rangefinder; its mount passes through an opening in the optical bar, and holds the adjustment glass on the optical axis. Since the glass itself is a disk with parallel faces, its longitudinal position is not critical. But it must be far enough from the objective to let all the converging rays pass through the lens.

END WINDOWS

The two functions of the end windows are to provide a transparent, gastight seal and to provide a means for correcting the accumulated errors of the entire optical system of the rangefinder, Each window is an optical wedge with an extremely small angle; rotation of a window will cause a small change in the apparent parallactic angle.

OVERHAUL

In this section of the chapter we will cover the disassembly, reassembly, and collimation of the rangefinder Mk 42 Mod 27. We are using the Mk 42 Mod 27 because it covers everything that will be found in other rangefinders.

Most of the repairs made on the rangefinder will be performed on the parent ship, since it is a large instrument and hard to handle. (NOTE: Overhaul only to the extent needed to make repairs.)

DISASSEMBLY

Before you begin disassembly, take the cover plate off the wiring box, and remove all the electrical connections. Tag and number each wire and cable as you disconnect it, to help ensure correct replacement. Next release the gas pressure through the outlet valve before beginning to disassemble the rangefinder. (Note: During the disassembly and reassembly procedures, be careful not to damage the machined bearing surfaces.)

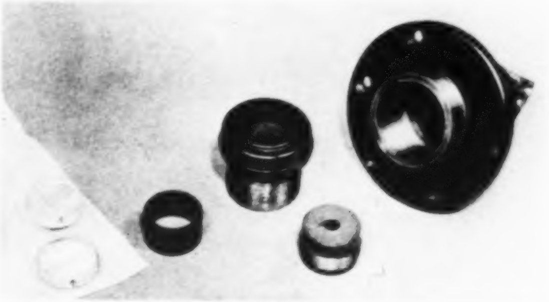
The first items to remove are the END-REFLECTOR ASSEMBLIES; follow these steps in removing them:

1. Remove 14 screws from the end box flange cover plates, and remove the plates.
2. Back off the 12 securing bolts at each end box.
3. Remove the securing bolts and lift off the end boxes. You will need help for this—it is a two-man job.
4. Disengage the control rods from the internal adjustor-prism assemblies by removing one securing screw at each end of the rangefinder.
5. Now remove the two end reflector brackets.

Next remove the headrest by taking out the two screws that secure it, and remove the rubber eyeguards of the oculars. Loosen the interpupillary and filter scales, so you can rotate them to get at the faceplate screws. Remove the faceplate screws and the faceplate. Remove the faceplate support by taking out the 18 screws that secure it.

Removal of the CORRECTION-WEDGE ASSEMBLY is the next step.

1. Remove the six screws by which the scale reading telescope is mounted, and lift out the telescope.
2. Loosen the locking ring of the telescope, and unscrew the eyepiece mount from the body. Remove the eyepiece doublets by taking out the setscrew and unscrewing the retaining ring and diaphragm. Figure 7-7 shows these parts.



148.47

Figure 7-7.—Correction-scale telescope, with eyepiece disassembled.

3. Take out two setscrews, and remove the telescope prism mount. Unscrew the retaining ring to free the sealing glass.
4. Remove the cap plug and illuminator housing from the correction-wedge mount. This exposes the sealing glass plate. Remove the plate and the lucite illuminator rod.
5. Turn the assembly so it will pass through the opening in the tube, and carefully remove it, as in figure 7-8. The insert in the figure shows how to disconnect the swivel pin socket from the drive shaft.
6. Disengage the drive shaft and pull it out through the correction-wedge opening.
7. Remove 14 screws from the correction-wedge knob plate, and lift off the knob and plate.
8. Remove the spring stops from the side of the correction-wedge assembly. Now free the wedge cell by taking out the three screws.
9. Remove the setscrew from the wedge cell; unscrew the retaining ring, and take out the wedge.
10. On the opposite side of the wedge assembly, free the mount and scale by unscrewing the two locking rings and the ball bearing ring. (See fig. 7-9).
11. Remove the two screws that secure the scale index bracket, and take off the bracket.

Now remove the six screws that engage the ADJUSTER-PRISM SHIFT to its shaft; lift out the prism shift. Disconnect the shaft by reaching

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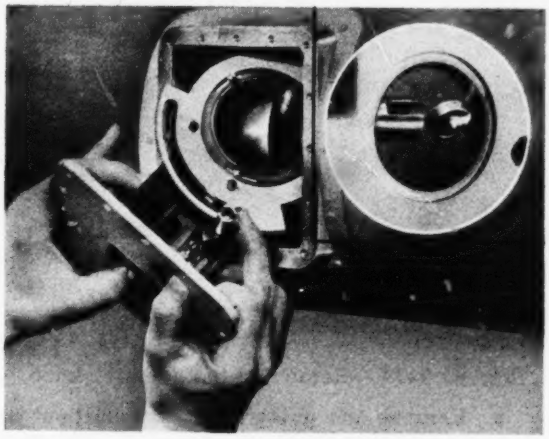
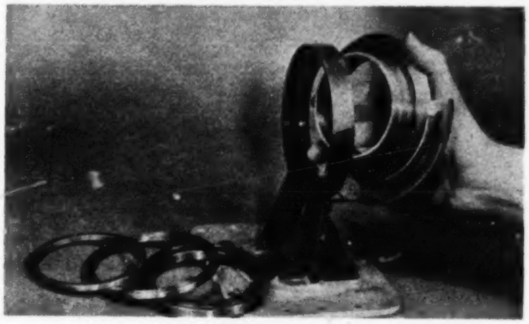


148.48
Figure 7-8.—Removing the correction-wedge assembly.



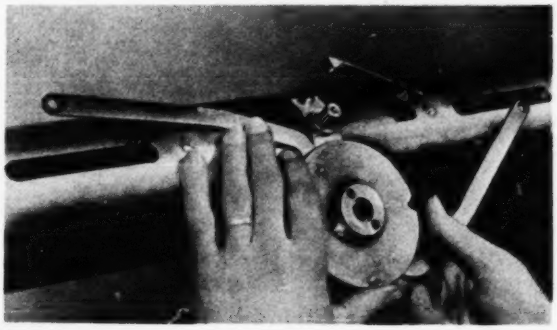
148.49
Figure 7-9.—Removing scale from the correction-wedge mount.

in through the faceplate opening and releasing the lockscrew.

Next set the CHANGE-OF-MAGNIFICATION KNOB at 12 power and then remove the assembly as follows:

1. On the change-of-magnification shift, release the arms from the erecting-lens mounts. Remove the screw from the center of the disk, and lift off the whole unit as in figure 7-10. Detach the remaining spring bracket.

2. Remove two screws from each lens-mount guide post, and lift out the posts. (The ends of these posts can be seen protruding through the sides in fig. 7-10.)



148.50
Figure 7-10.—Removing the change-of-magnification unit.

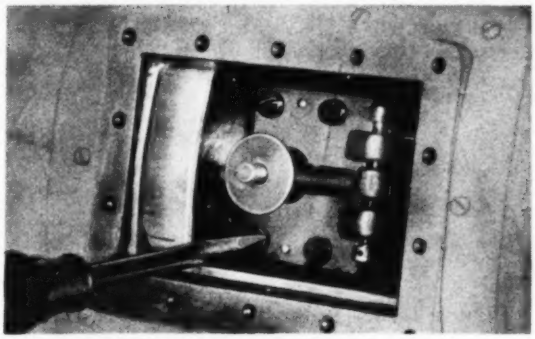
Now remove the RETICLE ASSEMBLIES as follows: (Refer to fig. 7-1 as needed.)

1. Remove the 14 screws that secure the illuminator plate, and lift it off.

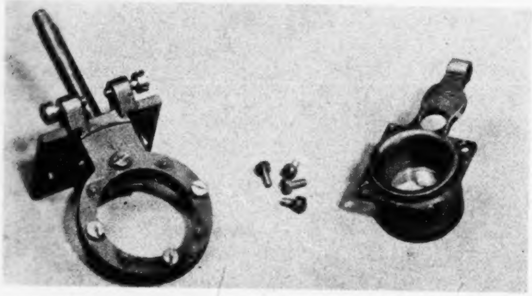
2. Remove the four screws from the reticle mount, as in figure 7-11 and lift out the whole reticle assembly.

3. Unscrew the clamping ring and pull out the lucite illuminator rod.

4. Loosen the four eccentric screws, and remove the four clamping screws. Lift out the reticle mount. (Fig 7-12.)



148.51
Figure 7-11.—Releasing the reticle mount assembly.



148.52

Figure 7-12.—Reticle mount removed from assembly.

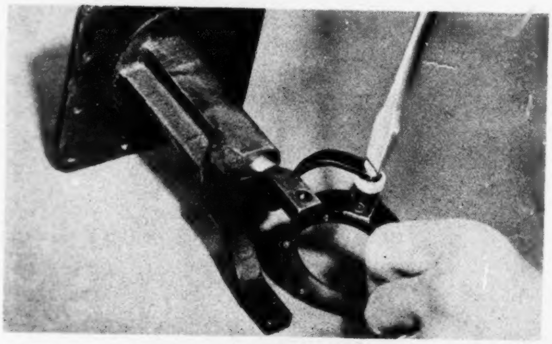
5. Back off the setscrew on the reticle mount. Unscrew the retaining ring with a pin wrench, and remove the reticle.

Remove the SEARCHLIGHT FILTER KNOB by taking out the six screws that secure it to its shaft. Free the shaft by reaching in through the right reticle opening and releasing the lockscrew; withdraw the shaft.

Remove the HEIGHT-ADJUSTER ASSEMBLY as follows:

1. Remove the 12 screws that secure the assembly to the tube. Turn the assembly through approximately 90°, and lift out.

2. Remove the two pivot screws from the unit. Detach the cell mount by freeing the control arm from the shaft, as in figure 7-13.



148.53

Figure 7-13.—Releasing the control arm.

3. Drive out the taper pin that secures the adjustment knob, and remove the knob. (See fig. 7-14.)

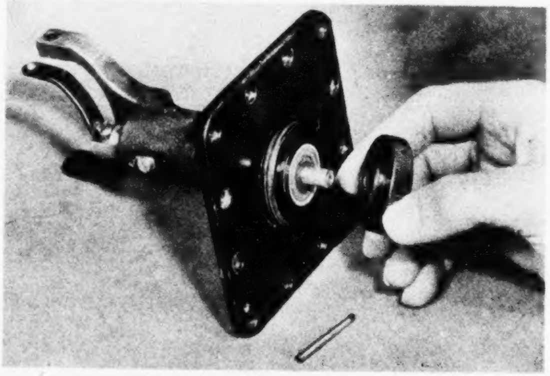


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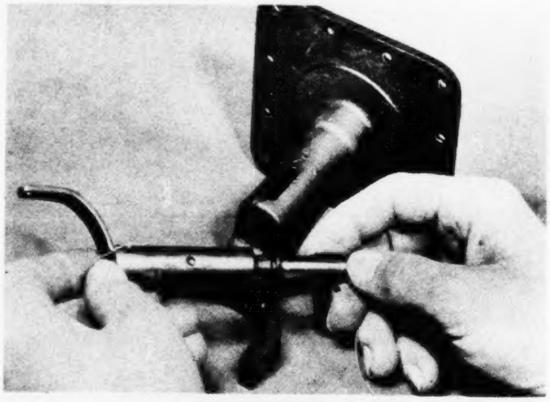
Figure 7-14.—Removing the adjuster knob.

4. Remove the guide screw and pull out the control arm shaft. (Fig. 7-15.)



148.55

Figure 7-15.—Removing the control-arm shaft.

5. Remove the six screws from the retaining ring on the cell mount, and take out the adjuster glass.

Take out the TARGET-CENTERING ADJUSTMENT, and remove the two illuminator plates. Remove the internal target assembly. Take out the four screws that secure the internal-adjuster target, and lift it out of its assembly.

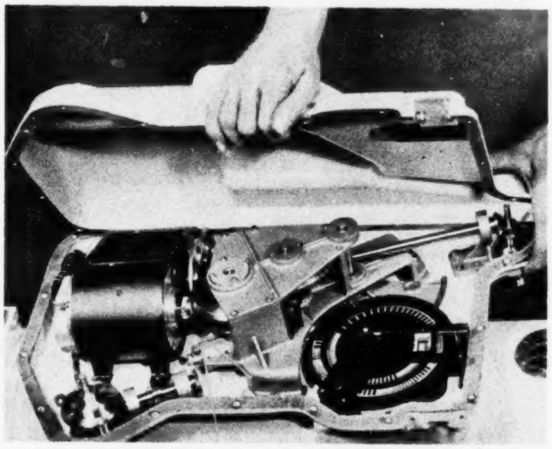
Unscrew the inlet-valve plug from the GASSING-PLUG MOUNT. This exposes the locknut for the internal gas-line connection; use a pin wrench to unscrew the nut. Now remove the six screws from the gassing-plug mount, and lift it off.

Free the INTERNAL-SCALE READING TELESCOPE by taking out the six screws that secure it. Turn the telescope while withdrawing it, so that the prism mount will safely clear the opening.

Now disassemble the CHANGE-OF-RANGE ASSEMBLY as follows:

1. Back off the range-knob lockscrew, and pull off the knob and its pushbutton.

2. Remove the range-scale illuminator housing. Remove 17 screws from the gear box cover, and lift it off (fig. 7-16).



148.56

Figure 7-16.—Removing the gear-box cover.

3. Free the range-scale index by taking out four screws; lift the index from its dowel pin.

4. Carefully mark the position of the scale, to help ensure correct replacement when reassembling. Take out the four screws that secure the scale, and remove it (fig. 7-17).

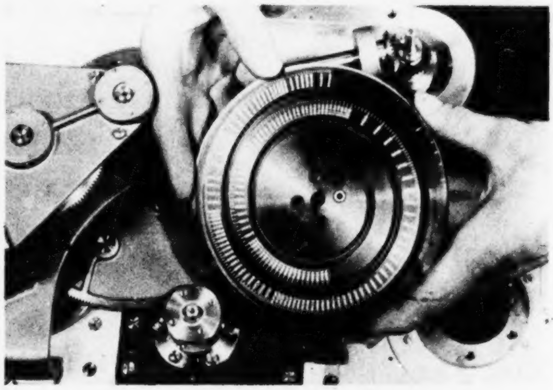
5. Release the internal-scale gear bracket by taking out four screws; remove the bracket and its tension spring.

6. Release the change-of-range gear housing by taking out three screws. Drive out the two taper pins (see insert of fig. 7-18). Disengage the drive shaft and lift out the gear housing, as in figure 7-18.

7. Through the holes in the range-knob housing gear, take out four screws to release the gear; then remove it.

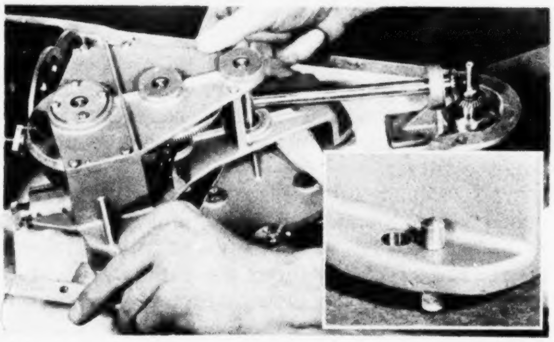
8. Remove four screws from under the housing, and take out the input drive gear.

9. Remove the four bracket lugs and then carefully lift out the synchro generator assembly, drawing the wires up through the housing (fig. 7-19).



148.57

Figure 7-17.—Removing the scale.



148.58

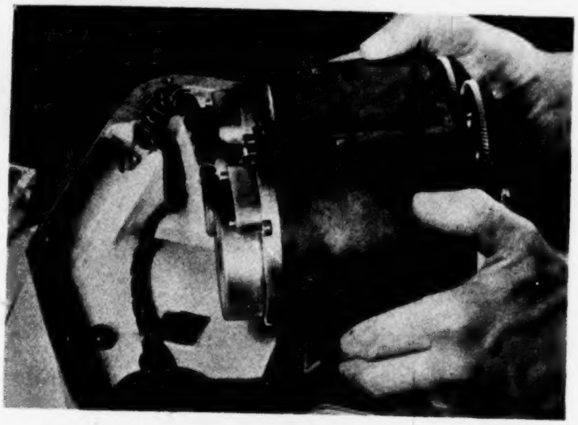
Figure 7-18.—Removing the gear housing.

10. Unscrew the plug cap and take out the 16 screws that secure the compensator. Turn the compensator to the right to disengage it from the drive shaft; then lift it out.

11. Pull the shaft from the range drive gear assembly. Remove 12 screws from the assembly, and carefully lift it out.

12. Remove the remaining 19 screws to release the support.

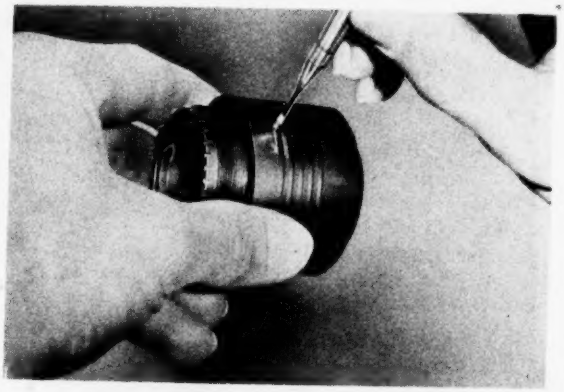
Take off the end counterweights, and pull the rubber gaskets from the inner side of all the openings. Remove the support cap and lock stud of the right main bearing. Now check carefully to be sure the inner tube is clear and free for safe withdrawal. Withdraw the tube and set it on blocks for further disassembly.



148.59
Figure 7-19.—Removing the synchro generator assembly.

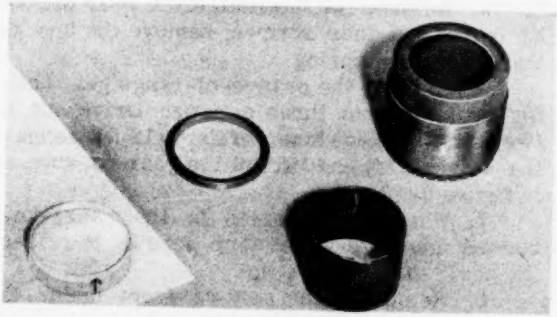
Disassembly of the INNER TUBE is next, to disassemble follow these steps:

1. Remove four screws at each end of the tube, and swing out the searchlight filters. This will expose the screws that secure each filter to its control rod. Remove these screws and take off the filters.
2. Disengage the searchlight filter control rods at each end of the tube, and remove them.
3. Take out four screws to release the control gear assembly (near the center of the tube, and a little to the right). Remove the control gear assembly.
4. Just inside the correction-wedge opening, you will find a screw-head taper pin. Back it off. Now pull out the left adjuster rod, and remove its sliding support.
5. Release the right adjuster-rod support—(the locking pin is just inside the compensator opening) and remove it.
6. By releasing a screw, break the offset coupling to free the two right rods. Then remove the adjuster-gear housing at the left center of the tube.
7. Unscrew and remove the two objective mounts for the correction-scale reading telescope.
8. Remove the four hold brackets for the gas line, and withdraw the line.
9. Remove six screws at each end of the tube, and remove the small rod guides. Then slide out the tube bracket assemblies.
10. Unscrew the cap and lock stud to free the optical bar. Slide the bar over to the right, off its support bearing.
11. Now release the internal adjuster tube bracket on the right, and remove it from the tube.
12. Withdraw the optical bar from the inner tube.
13. Remove the two slide tubes from the optical bar. (Use a threaded plug wrench.)
14. Take out two screws from each slide tube, and remove the lens mounts.
15. Back off the setscrew on each lens mount (fig. 7-20), and screw out the threaded cell.



148.60
Figure 7-20.—Releasing the threaded cell.

16. Remove the setscrew from the front of the cell. Unscrew the retaining ring with a pin wrench, and remove the front lens and the separating ring. (Always protect the lenses from dust and scratches by wrapping them carefully in lens paper. Mark the lenses showing the direction of light on each one, as in fig. 7-21.)



148.61
Figure 7-21.—Erector cell, disassembled.

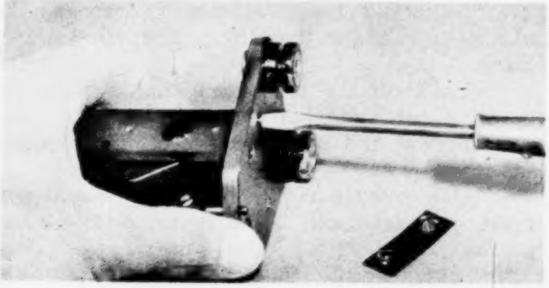
17. Back off the other setscrew, and unscrew the retaining ring; then remove the rear lens.

18. Remove the left section of the internal adjuster tube bracket.

Now remove and disassemble the EYEPIECE PRISM MOUNTS as follows:

1. Take out the two screws that secure the tension spring, and remove the spring.

2. Remove the two screws from the base of the mount, as in figure 7-22.

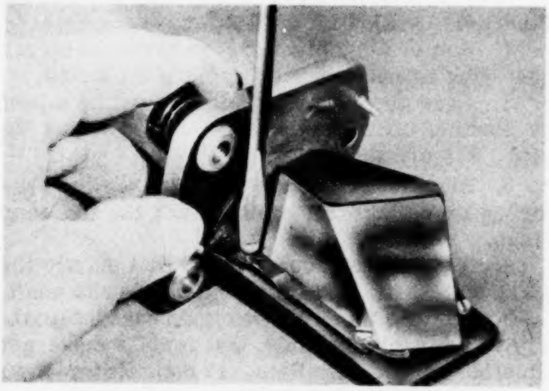


148.62

Figure 7-22.—Removing screws from base of mount.

3. Remove two screws from the angle bracket. The bracket is now free; lift it off.

4. Finally, remove the two screws from the holding clamp (fig. 7-23) and lift out the prism.



148.63

Figure 7-23.—Releasing the holding clamp.

Now disassemble the FACEPLATE AND COLOR-FILTER ASSEMBLY as follows:

1. Remove the center screw from each filter mount, and release the holding clamp.

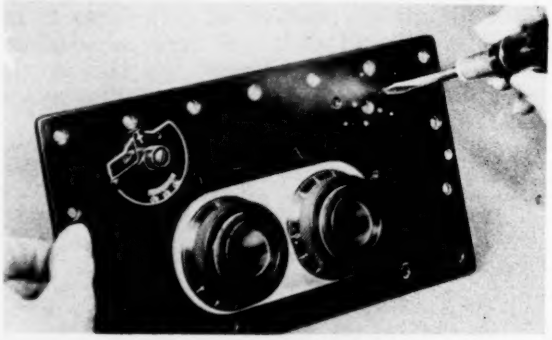
2. Remove the clamping screw from each filter mount, and remove the mounts.

3. Remove the setscrew from the density control knob, and take off the knob. Now remove the gear pinion from the back of the plate.

4. Remove the density control lockscrew and nut, and lift out the shaft.

5. Remove two screws from the two guide brackets, and lift off the gear rack.

6. Release the right gear bracket by removing three screws from the faceplate (fig. 7-24).



148.64

Figure 7-24.—Releasing the right gear bracket.

7. Back out the setscrew in the interpupillary adjustment knob, and remove the knob.

8. Remove the large washer screw from the left gear bracket, and remove the coupling and bracket from the faceplate.

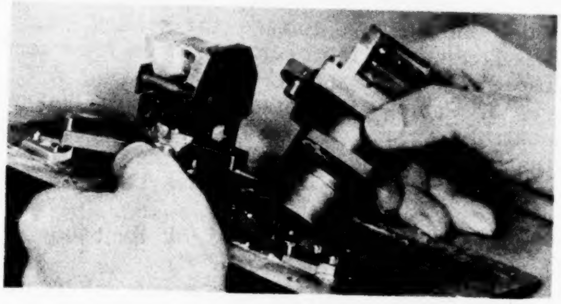
9. Take out the setscrew in each eyeguard ring, and unscrew the rings.

10. Remove the setscrew from each knurled ring; take out six screws from each retaining plate, and unscrew the diopter rings. You can now remove the eyepiece slides.

11. Remove the setscrew from each slide. Then remove the retaining ring, lenses, and spacing rings.

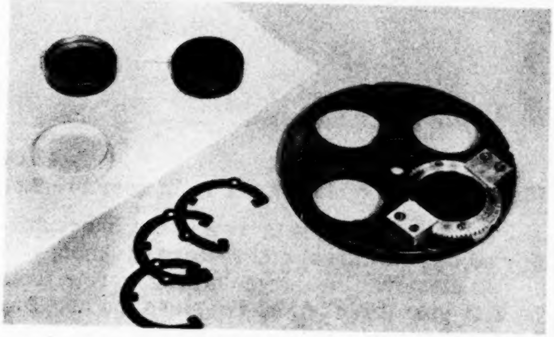
12. Lift both index dust rings off the faceplate. Take out the four screws that secure the right eyepiece prism mount; disengage the coupling and lift out the prism mount, as in figure 7-25. Remove the left prism mount in the same way.

13. Remove the two binding post screws on each rhomboid prism mount, and remove the holding-down plate and clamp.



148.65
Figure 7-25.—Removing the right eyepiece prism mount.

14. Mark the position of each filter in its mount, so you can put it back in the same place. Remove the securing clamps, and take out the filter disks. Figure 7-26 shows a filter mount disassembled.



148.66
Figure 7-26.—Filter mount, disassembled.

Now disassemble the END REFLECTORS, referring back to figure 7-2 to identify parts:

1. On each end reflector bracket, remove two screws from the split bearing on the prism pivots. Lift off the bracket.
2. From each bracket, take out the three adjustable locking bolts, and remove the reflector mount. Release the spring tension screw on each end of the mount.
3. Remove two screws to release the holding-down side clamp. Lift out the reflectors.
4. On each prism bracket, remove five screws and lift off the shield. Take out three screws, then the eccentric bolt, and detach the mount.
5. Release the holding-down plate, and remove the prism.

Next disassemble the INTERNAL RANGE-SCALE TELESCOPE as follows:

1. Unscrew the eyeguard ring. Back off the setscrew and unscrew the index and diopter ring.
2. Take out two screws to free the focusing key from its slot, and remove the eyepiece cell.
3. Remove two lockscrews, and unscrew the prism mount from its housing.
4. Use a pin wrench to unscrew the sealing-glass retaining ring; remove the glass.
5. Take out three screws to release the holding-down plate; then lift off the prism and its clamp.
6. Back off the lockscrew that secures the objective cell, and remove the cell. Take out the setscrew, and remove the retaining ring and lens.
7. Unscrew the retaining ring and diaphragm of the eyepiece cell. Remove the doublets and spacing rings.

To disassemble the CORRECTION-SCALE READING TELESCOPE do the following:

1. Loosen the locking ring and unscrew the eyepiece mount.
2. Remove the retaining ring setscrew; unscrew the retaining ring and diaphragm. Then remove the eyepiece doublets.
3. Remove two screws from each securing clamp of the prism, and remove the prism. Remove two setscrews to release the prism mount.
4. Unscrew the sealing-glass retaining ring, and remove the glass.

Now disassemble the INTERNAL-ADJUSTER TARGET ASSEMBLY as follows:

1. Remove two pivot screws from the target-centering adjustment, and remove the mount.
2. Free the centering plate from the mount by backing off the setscrew and unscrewing the ring. Remove the plate.
3. Remove the screw that secures the centering knob; take off the knob and the five stop rings.
4. Remove the four screws that secure the plate and shaft, and lift out the plate and shaft.
5. Remove three screws from each internal-adjuster target assembly, and remove the target illuminator mount. Remove the holding-down clamp, and take off the reflector glass.
6. Unscrew the retaining ring at the other end of the mount, and remove the diffusing glass and spacing ring.
7. Remove the retaining strap from the target assembly, and back off the fine adjustment

screw to release the reticle mount. Back off a setscrew and unscrew the reticle cell from the mount.

8. Remove the setscrew from each end of the cell; remove the retaining ring and the reticle target.

9. Loosen the setscrew in the opposite end of the mount, and unscrew the objective cell. Disassemble the cell by taking out its setscrew and unscrewing the retaining ring.

10. At the wedge-cell end of the target assembly, remove the two retaining strap screws. Loosen the fine adjustment screws, and slide out the wedge-cell mount.

11. Free the wedge-cell from its mount by backing off a setscrew in the lug. Disassemble the cell by taking out the setscrew and retaining ring.

The SEARCHLIGHT-FILTER can be disassembled next by removing two split bearing caps, and taking off the pivot bearing of each assembly. After removing the lockscrew near the base, you can unscrew the cell with a pin wrench. Remove the setscrew to release the retaining ring; remove the ring, and take out the spacing ring and filter.

Now disassemble the COMPENSATOR UNIT as follows:

1. Unscrew the plug cap. Take out the 16 screws that secure the compensator assembly to the outer tube. Turn the assembly to the right to disengage it from the drive shaft, and then lift it out of the rangefinder.

2. Remove the eight screws that hold the lucite illuminator rod, and remove it from the outside surface of the compensator.

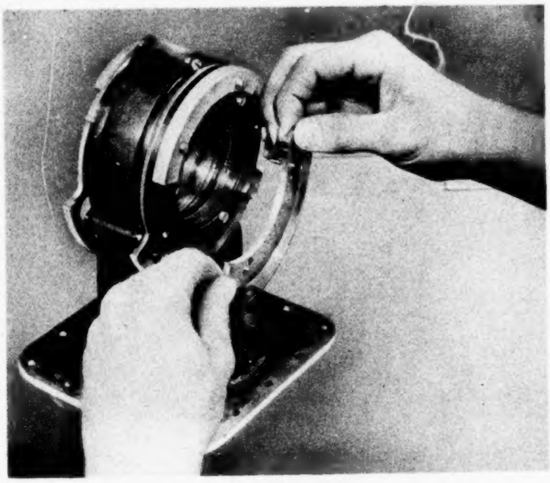
3. Remove the scale index by taking out the two screws that hold it.

4. Remove the two screws that hold the scale in place; then lift it off, as in figure 7-27.

5. Remove the counterweight from above the scales. Remove three screws from the support ring (under the scale and counterweight), and remove it.

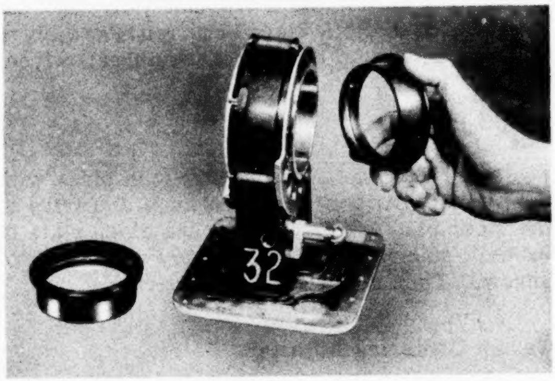
6. Remove the two wedge-cells—one from each side of the compensator mount—as in figure 7-28. To disassemble a wedge-cell, back out the setscrew, screw out the retaining ring, and remove the wedge.

7. Remove the two stop screws from the compensator unit. Remove the three screws and clamps through the hole in each gear segment, and lift the two segments off the assembly, as in figure 7-29.



148.67

Figure 7-27.—Removing the compensator scale.

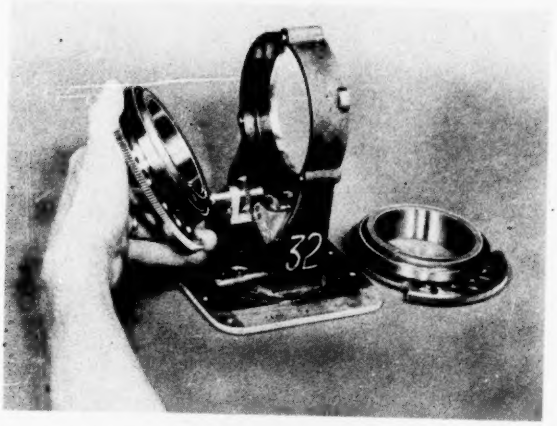


148.68

Figure 7-28.—Removing the wedge cells.

8. Unscrew the locking ring on each gear segment, and remove the ball bearing. If necessary, remove the gear bracket by taking out the three screws that secure it.

Remove the END WINDOWS from the end boxes by removing the four screws that secure the cover plate, and lift it off. Remove the clamping ring and scale, and unscrew the mount. If it is necessary to remove the wedge from its mount, apply slow heat to soften the sealing compound.



148.69
Figure 7-29.—Removing the gear segments.

REASSEMBLY AND COLLIMATION

In general, you can reassemble the rangefinder by following the disassembly directions in reverse. In the following sections a few pointers that will be helpful during reassembly are given.

Height Adjuster

Insert the shaft, and secure it in place with the slot key. Attach the control knob, and drive in the taper pin. After replacing the glass plate in its cell, secure it in the assembly with two pivot screws. Then attach the control arm.

Target Centering Adjuster

Insert the shaft in the air-pressure diaphragm, and turn the shaft back one full turn from the bottom. Attach the shaft and the knob support to the plate with four screws. After securing the centering plate and retaining ring in the mount, engage the mount to the shaft coupling and attach it with two pivot screws. Set the four heavy stop rings against the pin for a clockwise stop; then add the remaining thin washer and the spring, so that the lug of the washer engages in the hole in the knob. Before attaching the knob, be sure that the doweled shaft and the locking rings are properly engaged. You will have to apply pressure from the bottom of the shaft to attach the knob screw.

Reassembly of the Optical Bar

Use a threaded plug wrench to slide in the two erecting lens mounts. Secure the two mounts in the bar by means of their guide posts and screws. Replace the change-of-magnification shift and arms, then the spring bracket.

Attach the two eyepiece prisms temporarily by means of the adjustable locking bolts and screws. Slide in the two objective lenses at the ends of the bar, and fasten them with the position bolts. Turn on the two locking rings, then the securing rings. That is as far as you proceed now. You will make the final setting of the locking rings when you collimate the optical bar.

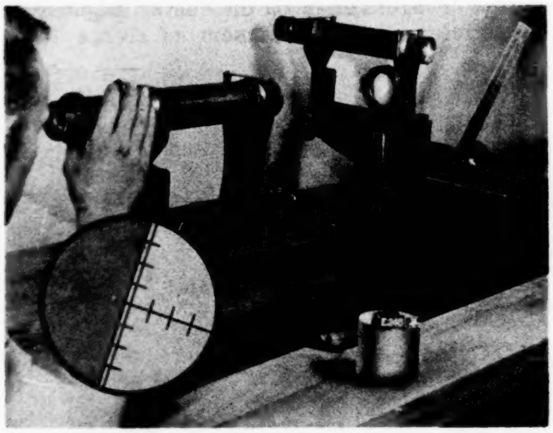
Correction Wedge And Compensator Unit

After attaching the drive gear, put the scale index bracket in place. Set in the ball-bearing ring, and insert the mount and scale in the opposite side of the assembly. Now attach the two locking rings; the smaller ring locks the mount to the bearing; the larger ring locks the mount to the assembly itself. Secure the wedge cell with three screws; then attach the two spring stops.

First set the ball bearing in place in each segment, and lock it with the ring. After attaching the two gear brackets to the unit, replace the gear segments and secure each of them with three screws and clamps. Be sure the gears mesh properly. Replace the two stop screws. Put each wedge in its cell, and secure it with the retaining ring and setscrew. Replace the two cells in the compensator unit, and secure it temporarily with three screws. (You will secure it permanently during collimation.) After setting in the support ring and the two counterweights, secure the scale with two screws. Now attach the scale index and the lucite rod.

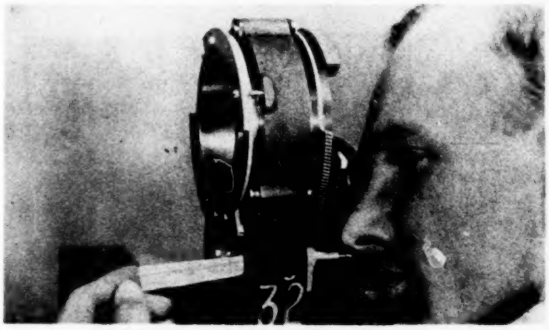
Now you are ready to collimate the compensator, the correction wedge, and the main optical bar. Use a Mk 4 telescope collimator, or a Mk 2 spotting-glass collimator which has been adapted for use with the Mk 42 rangefinder. Collimate the compensator first.

COLLIMATION OF THE COMPENSATOR.—The compensator is positioned in the rangefinder at an angle of 25°, therefore it will have to be collimated at that angle. Set the crossline of the collimator telescopes at an angle of 25°, as in figure 7-30. Use a level protractor set at an angle of 25°. Use an auxiliary objective to get a sharp image of the protractor; rotate the telescope until its crossline is parallel to the edge of the protractor scale.



148.70
Figure 7-30.—Adjusting the collimator telescopes.

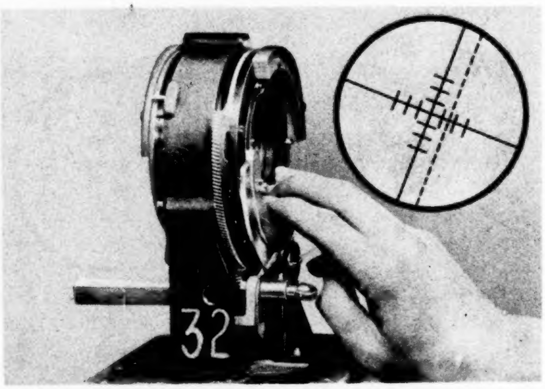
Mount the compensator on parallel bars. Remove the left wedge. Set the scale at 1,591 yards—the zero setting for the Mk 42. Lock the scale at this position with a temporary wedge, as in figure 7-31.



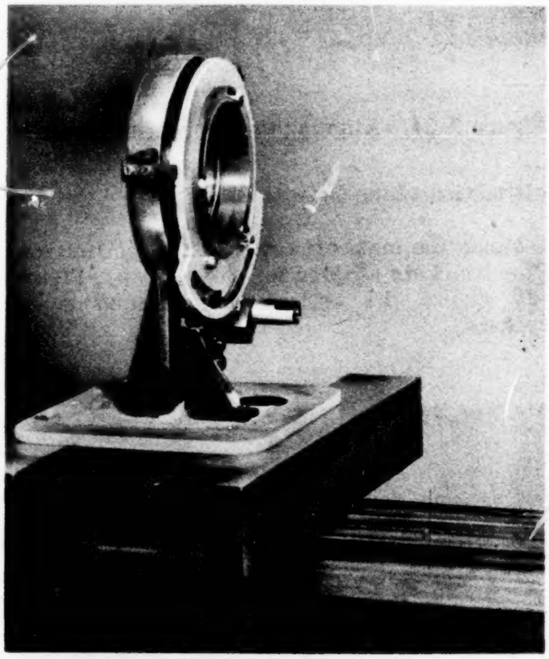
148.71
Figure 7-31.—Locking the scale.

Rotate the right wedge until its vertical lines are parallel to those of the collimator telescope, as in figure 7-32.

Replace the left wedge and rotate it to bring both sets of crosslines into coincidence. Now remove the temporary wedge.

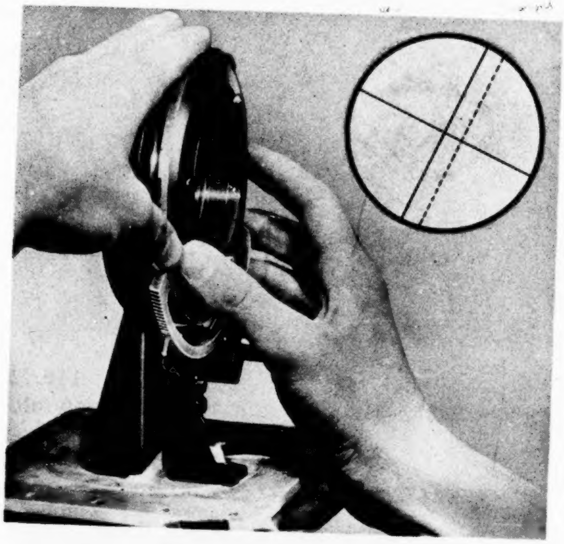


148.72
Figure 7-32.—Bringing the vertical lines into coincidence.



148.73
Figure 7-33.—Correction wedge mounted for collimation.

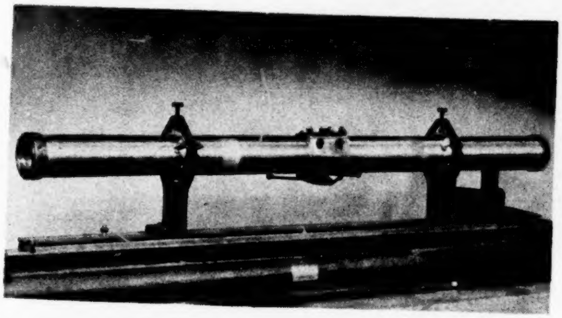
COLLIMATION OF THE CORRECTION WEDGE.—Place the correction wedge on the parallel bars, as in figure 7-33. Set the correction scale at 60. Now, with the collimator crosslines still at an angle of 25°, rotate the correction wedge until its vertical line is superimposed on that of the collimator telescope, as in figure 7-34.



148.74
Figure 7-34.—Aligning the correction wedge.

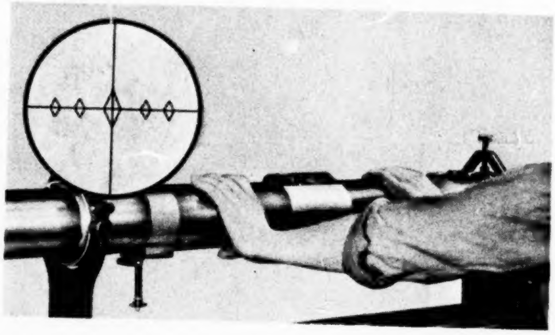
Collimation of the Optical Bar

Mount the main optical bar on the collimator, in the brackets adapted for that purpose. Figure 7-35 shows the optical bar mounted in its brackets.



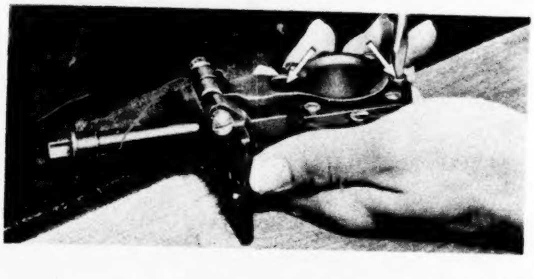
148.75
Figure 7-35.—Optical bar, mounted on the collimator.

Remove the eyepiece prisms, and insert the left reticle. By turning the telescope adjusting screws, superimpose the intersection of the collimator crosslines on the center diamond of the reticle, as in the insert of figure 7-36.



148/76
Figure 7-36.—Centering the diamond.

Now rotate the optical bar through 180°. Sight through the telescope, and observe the position of the diamond in relation to the crosslines. It will probably be off the intersection. To center the diamond on the mechanical axis of the optical bar, loosen the screws, as in figure 7-37.

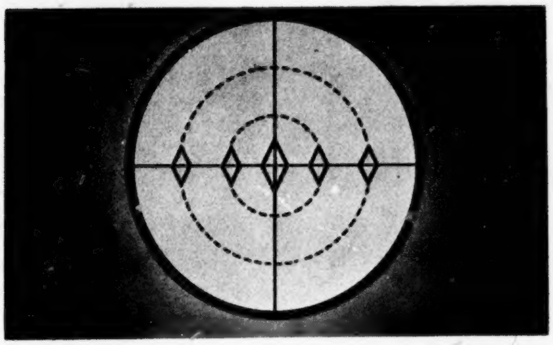


148.77
Figure 7-37.—Adjusting the reticle.

Now repeat the test, and make a further adjustment if necessary. Figure 7-38 shows the path of the diamonds on a properly collimated reticle when the optical bar is rotated through 360°.

To adjust the right reticle, reverse the optical bar on the collimator and repeat the collimation procedure.

Replace the eyepiece prisms, and set the diopter scales at zero. Set the main faceplate assembly in place on the optical bar. Use a



148.78

Figure 7-38.—Diamonds properly collimated through 360° rotation.

dynameter to check the two eyepieces for equal magnification. Put an aperture stop over the objectives, one at a time, and check for definition. Check the two telescope systems for equal magnification. To adjust the magnification, follow the directions given in chapter 6 under magnification.

Now correct for true lines of sight. First, replace the reticles. Set on the faceplate, and take a reading with a comparator. The diamonds must lie in the same horizontal plane. To adjust the dipvergence, follow the directions given in chapter 6 under dipvergence.

Replacing The Optical Bar

To replace the optical bar in the inner tube, follow these steps:

1. Remove both reticle assemblies from the optical bar.
2. Replace the bar in the inner tube, and move it up to its bearing.
3. Mount the right internal adjuster tube.
4. Lift the optical bar onto its bearings; push it into place, and lock it there.
5. Mount the left internal adjuster tube, and secure it with two screws in each bracket.
6. Secure both tube-bracket assemblies, one in each end of the inner tube.
7. Insert the gas line, and secure its four brackets. Put the valve in position in the line; you will connect it later.
8. Secure each of the two objective mounts for the correction-scale reading telescope with four screws.
9. Secure the prism adjuster-gear housing (to the left of the eyepiece opening) with four screws.
10. Set the control-gear housing in place (at the right of the eyepiece opening).
11. Slide in the searchlight-filter control rods—one through each end of the tube. Engage them with the control-housing gear.
12. Replace the two internal adjuster rods. The left rod, and the inner section of the right rod, engage in the gear housing.
13. Attach the outer section of the right internal adjuster rod in its coupling. Replace the two sliding supports.
14. Attach each of the searchlight filters to its control rod. Twist each filter counterclockwise until it is secure in its base in the tube.

Assembly of the Outer Tube

Now replace the inner tube in the outer tube, and lock it in position. Then follow these steps:

1. Replace the rubber gaskets in all the tube openings.
2. Mount and secure the faceplate support. (Do not forget to give all machined surfaces a thin coat of grease during reassembly.)
3. Insert and engage the adjuster-prism shaft. Secure it with the small lockscrew at its inner end.
4. Position the change-of-magnification knob on its stop, and secure it with eight screws.
5. Engage the searchlight-filter knob drive shaft, and secure it with its inner lockscrew. Replace the knob.
6. Replace and secure the height-adjuster assembly.
7. Replace the target-centering adjustment, and secure it with its six screws.
8. Insert the two internal-adjuster target assemblies, and secure each with its four screws.
9. Attach the gassing-plug mount. Align the inlet-valve opening with the gas-line connection, and secure the line with the locknut. After attaching the gassing-mount plate, replace the inlet-valve plug with a plug wrench.
10. Set the change-of-magnification knob at 12 power. Then replace the two reticle assemblies, and secure each with its four screws.
11. Set the correction-knob assembly in place, reaching through the correction-wedge opening to engage the drive shaft.
12. Replace the correction-wedge assembly; then reach through the opening with a wire hook

to engage it to its drive shaft. Secure the assembly with its 16 screws. Insert the lucite rod, and attach the lug cap.

13. Mount the correction-scale reading telescope and secure it with six screws.

14. Replace the gear-box support, and secure it with its 19 screws. Secure the range drive assembly with 12 screws. Engage the drive shaft.

15. Carefully connect the compensator assembly to its drive shaft, and secure it in place.

16. Replace the internal-scale reading telescope. (Turn it at an angle to work it through the opening without banging its prism mount.)

17. Attach the wires for the contact switch; then replace the synchro generator assembly and secure it with its four bracket lugs.

18. Secure the range-knob gear in place. After setting in the drive gear, replace the gear housing.

19. Carefully mesh the gear segment with the range drive assembly, and engage the bevel gear to the synchro generator. Insert the two taper pins in the gear brackets, and tap them into place; then secure the brackets with their screws.

20. Mesh the input drive shaft, and secure it in place. Replace the internal-scale gear bracket and its tension spring.

21. Set the range scale in place with the gearing at the extreme stop, and with the scale set accordingly. Replace the scale index on its dowel pin, and secure it with four screws.

22. Mount the main faceplate and color-filter assembly, and secure it with 18 screws.

23. Replace the two counterweights at the ends of the rangefinder.

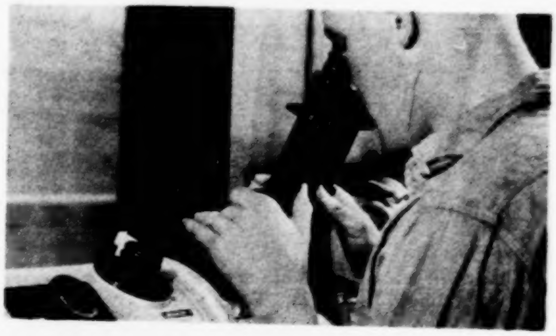
24. Connect each end reflector to its control rod, and secure the end-reflector brackets.

FINAL CHECKING

Now the rangefinder is ready for final checking on an outside target. Mount the rangefinder where it has an unobstructed line of sight toward a target at an accurately known range of 2,000 yards or more. Then follow these steps:

1. Use a comparator, as in figure 7-39, to check the alignment of the reticle diamonds. If the faceplate is not square with the line of sight, adjust it.

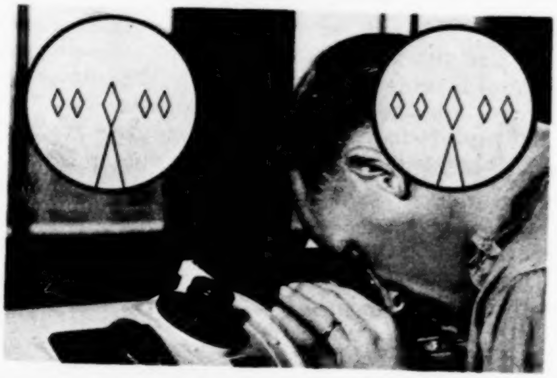
2. Train the rangefinder on the outside target, and use an auxiliary telescope to check for parallax. To remove parallax, release the locking ring on the objective mount, and adjust the position of the objective.



148.79

Figure 7-39.—Checking the faceplate position.

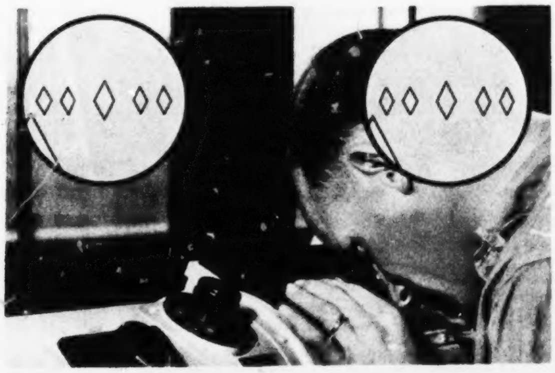
3. Set the height adjuster at midthrow, and check the height adjustment against your outside target. The inserts in figure 7-40 show an improper adjustment. To bring the two target images to the same height, raise or lower one of the images by rotating the corresponding end reflector.



148.80

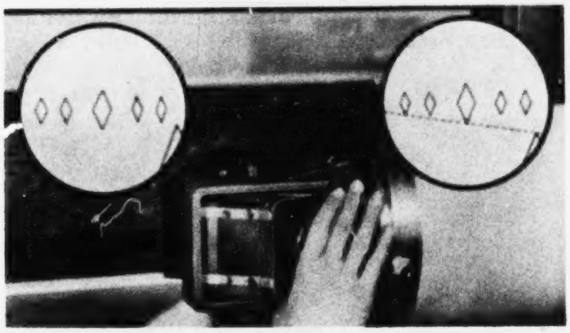
Figure 7-40.—Checking the height adjustment.

4. Now check for tilt of field. Train the rangefinder to bring the external target into the extreme left of the field. If necessary, use the height adjuster to bring the two target images to exactly the same height relative to the left-hand diamonds, as in the inserts of figure 7-41. Then train the rangefinder to bring the target to the extreme right of the field. A difference in height of the target images relative to the right-hand diamonds, as in the inserts of figure 7-42, shows tilt of field. Correct it by rotation of the end reflector, as in figure 7-42.



148.81

Figure 7-41.—Checking for tilt of field.



148.82

Figure 7-42.—Correcting tilt of field.

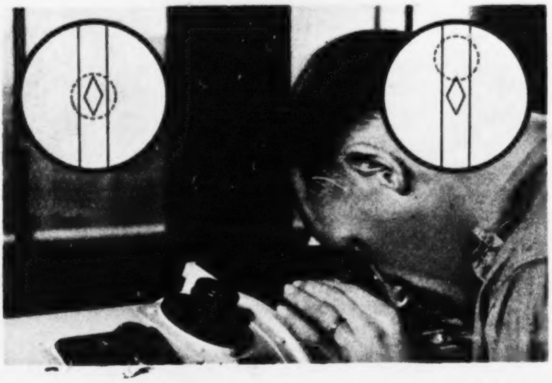
5. Range on your external target, and carefully read the range through the internal-scale reading telescope. Compare the reading of the external scale; it must be the same, within one unit of error.

Now secure the gear-box cover in place, and attach the range scale illuminator housing. Replace the range knob and its electrical push-button, and secure the knob with its lockscrew.

INTERNAL ADJUSTMENTS

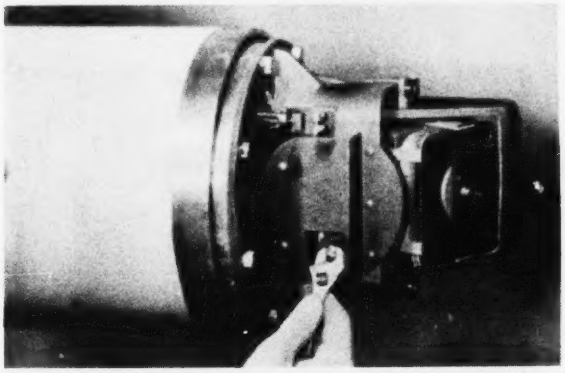
To adjust the internal adjuster system, follow these steps:

1. Set the correction scale at 60—its mid-position; use temporary illumination for this reading.
2. Set the range scale at 6,000 yards; cut in the internal-adjuster prism shift, and illuminate the internal targets.
3. Check the height of the light beam on each side, as in figure 7-43. To adjust the height of the beam, loosen the three adjuster penta-prism bracket screws and turn the eccentric bolt, as in figure 7-44.



148.83

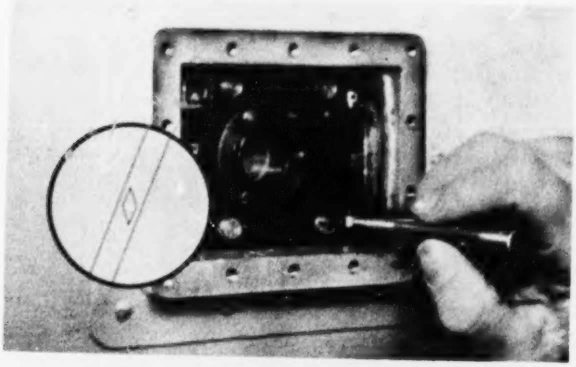
Figure 7-43.—Checking internal target light.



148.84

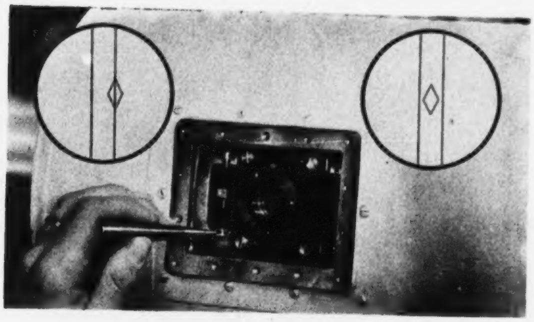
Figure 7-44.—Aligning the adjuster penta-prism bracket.

4. Examine both targets for lean. If one of them appears to lean, as in the insert of figure 7-45, adjust the internal target objective on the OPPOSITE side. The position of the target objective is controlled by the two screws shown in figure 7-45. Slack off one of them and tighten the other.
5. Check the internal targets for true stereoscopic reading. Set the internal adjuster scale at 60, the range scale at 6,000, and the target-centering knob at midthrow. Now sight through the eyepieces without moving the range knob. The internal targets should make stereoscopic



148.85
Figure 7-45.—Adjusting the internal target objective.

contact with the center diamonds of the reticles. If they do not, adjust the auxiliary internal adjuster wedge as in figure 7-46, and then repeat the test.



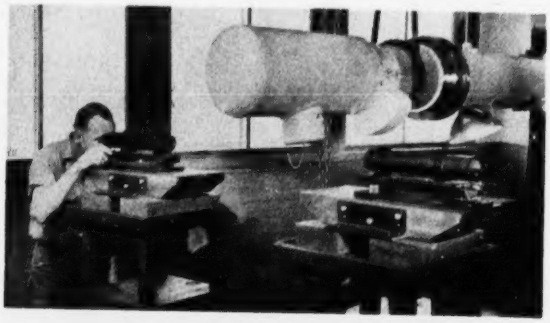
148.86
Figure 7-46.-Rotation of the auxiliary internal adjuster wedge.

Replace all illuminating and cover plates on the rangefinder. Replace the windows and scales in the end boxes; mount the end boxes and secure them in place.

Now you are ready to check the alignment of the mechanical and optical axes of the rangefinder. Follow these steps:

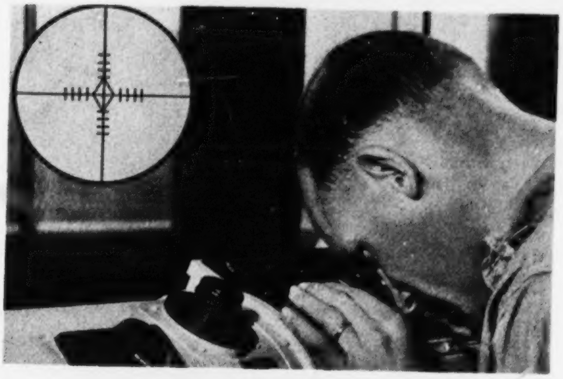
1. With the rangefinder hoisted up out of the way, line up two Mk 8 telescopes, as in figure 7-47, so that their reticle images are superimposed.

2. Lower the rangefinder onto a solid base with its left end between the collimators.



148.87
Figure 7-47.—Aligning the Mk 8 telescopes.

3. By adjusting the rangefinder bases, superimpose the image of the center diamond on the image of the collimator crossline intersection as in figure 7-48.

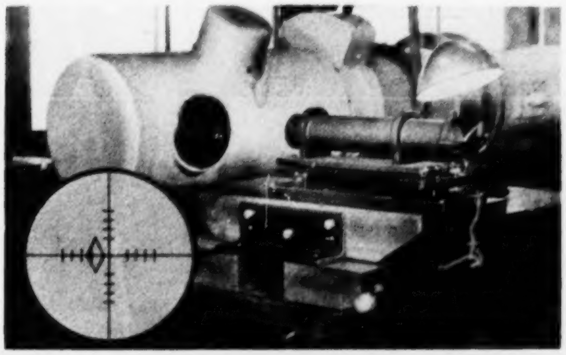


148.88
Figure 7-48.—Checking alignment with the first collimator.

4. Rotate the rangefinder through 180°, and compare the second collimator, as in figure 7-49. The allowable error is 4 minutes. If all previous adjustments were made correctly, the error should be within that tolerance. If it is not, it may be that the end reflectors are not properly seated, or that the reticle is improperly collimated. Find the error, and correct it.

5. Hoist the rangefinder out of the way again, and recheck the collimator alignment. Lower the rangefinder onto its blocks, and repeat the test.

Now range once more on a target at an accurately known distance. With the correction



148.89

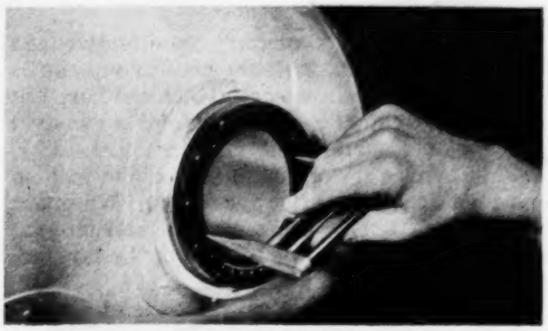
Figure 7-49.—Checking alignment with the second collimator.

wedge and height adjuster at midposition, make stereoscopic contact with your target. Read the internal scale, and check the result with the known distance. If there is an error, correct it by rotating the end windows, as in figure 7-50, using the engraved scale as a guide.

Replace the end-box cover plates and secure them with 14 screws each.

Charge the rangefinder with helium, following the direction in chapter 6 under drying and charging.

Finally, connect the wiring system. First, secure the connection blocks in the wiring box; then reconnect the individual wires, as tagged. Replace the junction boxes and cable clamps. Attach the illuminator housings, cables, and sockets. Check the reticles for equal illumination; if necessary, adjust the slots in their housings.



148.90

Figure 7-50.—Rotating the end window.

Now give the rangefinder one final range check. Then it is ready for use.

CHAPTER 8

SUBMARINE PERISCOPES

It is pointless to compare the effectiveness of the Navy's optical instruments—to say one is more useful or more essential than another. But we can say this: if a rangefinder or a gunsight telescope on a surface ship becomes a casualty, the ship can carry on; but a submarine with no periscope is out of effective action. We might add that of all the Navy's optical instruments, the submarine periscope is one of the largest, heaviest, and most complicated.

In action against another ship, the effectiveness of a submarine depends on its ability to keep out of sight. The only reason for building a ship capable of submerging is that it can get within striking distance of another ship without being seen. Yet at the same time, the men in the submarine must see the other ship. To do so, they depend on the periscope.

Optically, the submarine periscope is no more complicated than a large rangefinder. But because the periscope has several functions instead of just one, and because its designer has had to solve a number of special problems, the mechanical systems are intricate.

PERISCOPE DATA

The earliest submarines were built without provision for periscopes and therefore, when submerged, were forced to grope their way blindly.

In 1854, Marie Davey, a Frenchman, designed a sight tube for a submarine. The tube contained two mirrors, one above the other, at a 45° angle and facing in opposite directions. These mirrors, while providing some degree of sight to the submerged ship, were faulty at best; in 1872, prisms were substituted for mirrors.

Before the War Between the States, the submarine had not had a place among the ships of naval warfare. An American, Thomas H. Doughty, USN, was the inventor of the original periscope. Doughty's invention was not the result of study and research but was the result of necessity. During the campaign of the Red River, while he was serving aboard the monitor Osage, Confederate cavalry on the banks of the river kept up a steady series of surprise attacks upon the Union ships, which had no way of seeing over the banks. This led Doughty to seek some new method of watching the shores. He took a piece of lead pipe, fitted it with mirrors at either end, and ran it up through the turret. This makeshift periscope provided sight for the crew of the Osage.

The earliest periscope, other than a collapsible one designed late in the nineteenth century by Simon Lake and known as an omniscope or skalomniscope, was a fixed tube. Soon, however, provision was made to allow the tube to be raised and turned by hand. This was fairly satisfactory when the boat was traveling at a low rate of speed, but with increased speed the pressure was apt to bend the tube and throw the image out of line. Improved design resulted in a double tube, the outer one to resist pressure and the inner one to house the lens systems.

DEFINITIONS

To ensure a uniform method of definitions on submarines, a standard system of nomenclature is used in all correspondence, specifications, and plans relating to such instruments.

The periscope nearest the bow is called the No. 1 periscope. This is normally the observation periscope. The next periscope aft of the No. 1 periscope is called the No. 2 periscope. This is normally the attack periscope. In some newer type submarines, the periscopes are mounted side by side instead of fore and aft. In these submarines, the starboard periscope is No. 1, normally the attack periscope, and the port periscope is No. 2, normally the observation periscope.

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The term "ALTIPERISCOPE" is applied to instruments having the combined qualities of altiscopes and periscopes; they are also sometimes called altiscope-periscopes and altiazimuth instruments. With the altiperiscope, the upper prism is movable on a horizontal axis, so that by turning it, the observer can raise or lower his line of sight.

The term "UNIFOCAL" designates an instrument with only one magnification; a BIFOCAL instrument offers a choice of two magnifications. All of the periscopes in use today are of the bifocal type.

The NIGHT PERISCOPE is especially designed for use in dim light; it has high light transmission and a large exit pupil.

An ATTACK PERISCOPE is designed to allow the submarine to get as close as possible to the enemy without being seen. The diameter of its head section—the part that rises above the surface—is reduced to an absolute minimum.

The term "AZIMUTH CIRCLE," as applied to a periscope, refers to the graduated ring mounted below the packing gland in the conning tower. This is true except for periscopes which incorporate the electrical and electronic (E and E) adapter; on this type of periscope the azimuth circle is on the E and E adapter. The azimuth circle is used for taking bearings through the periscope.

DESIGN DESIGNATION

Submarine periscopes are under the technical cognizance of the Bureau of Ships. They have no Mark numbers. Instead, each separate design, or modification of a design, is assigned a DESIGN DESIGNATION made up of the following symbols:

1. A serial number for each design, or modification; these numbers are assigned by BuShips.
2. A letter indicating the manufacturer, using this code:
    K—Kollmorgen.
    S—Sperry.
3. A letter showing the type of instrument:
    A—bifocal altiperiscope.
    H—high-power altiperiscope.
    N—night periscope.
4. A number showing the length of the optical system, in feet (to the nearest foot).
5. The letter T may be used to show that the optics have been treated (by filming) to increase their light transmission.
6. If the outside diameter of the upper head section is less than two inches, this diameter, in inches, is added to the design designation, separated from the preceding symbols by a diagonal mark.
7. If the instrument is an altiperiscope, and if its field of view can be raised enough to include the zenith, the letters HA (meaning high angle) are added to the design designation.

Here is a typical design designation:

91KA4OT/1.414HA

Decoded, that means:

	91 K A 40 T 1.414 HA
Serial number of the design	91
The manufacturer, Kollmorgen	K
Type of instrument: bifocal altiperiscope	A
Length of the optical system, in feet	40
Coated optics	T
Outside diameter, in inches, of the upper head section	1.414
High angle	HA

Each individual instrument is assigned a registry number (the same as a serial number on other instruments). You will find the registry number cut or stamped on each periscope at its eyepiece end, and on all of its detachable fittings, such as the training handles. On the eyepiece box of each periscope you will find a nameplate, which shows the design designation, the registry number, and some of the optical characteristics, such as magnification and field of view.

THEORY AND DESIGN

Basically the periscope is a tube, with reflecting elements at the top and bottom, to raise the observer's line of sight. But the actual design is not that simple. The periscope designer must solve several special problems that are not encountered in the design of other optical instruments. He must make a compromise between conflicting requirements. Here are some of the problems:

First of all, the periscope has to be relatively long, as you can see in figure 8-1. It must be long enough to rise above the surface while the submarine is still far enough below to be invisible to surface craft. Optical lengths of periscopes in service run to 40 feet or more.

Another important requirement is that the upper head section—the part that sticks out of the water—must be as slender as possible, to escape detection by the enemy, and to create a minimum wake. The wake of the periscope, if seen by the enemy, would not only reveal the submarine's presence, but also would indicate its course.

When the periscope is not in use, it is lowered, for protection, into a well (fig. 8-1). But when the submarine is maneuvering into attack position, it will use its periscope, fully elevated, while underway submerged. During that time, the periscope will be dragged through the water at high speeds. The periscope, in spite of its slender construction, must be rigid enough to resist the bending effect of the water pressure that results from its own drag. The optical system must be so designed that the bending effect will not distort or displace the target image.

Another requirement is that the periscope must be able to scan the whole horizon; it must be provided with some means for sweeping through 360 degrees in azimuth. With a modern periscope, the submarine captain sweeps the horizon by rotating the entire instrument.

It would obviously be impractical to make the periscope an integral part of the hull. And because the periscope must be raised and lowered and rotated, it cannot be welded to the hull; it must pass through an opening in the hull. The design and packing of that opening create another serious problem. The packing must admit no water into the submarine, even under tremendous pressures. Yet the packing must be so designed that the periscope can be freely raised, lowered, and rotated within it.

The periscope itself must be completely waterproof. Since the submarine is so dependent on its periscope, there must be positive assurance that the internal optical surfaces will not fog up. This is done by keeping a pressure of 7 1/2 psi of nitrogen in the periscope at a suitable dewpoint. The head window and its bezel, and the joint by which the head is secured to the upper part of the tube, are in direct contact with the sea. And yet the leakage through them must be zero.

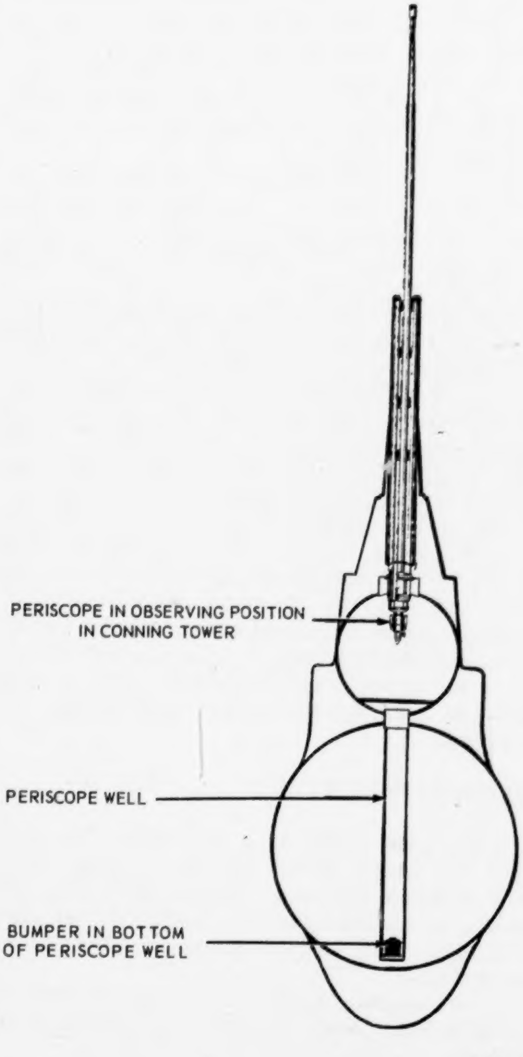
PERISCOPE IN OBSERVING POSITION IN CONNING TOWER
PERISCOPE WELL
BUMPER IN BOTTOM OF PERISCOPE WELL

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Figure 8-1.—Vertical section through a submarine, with periscope elevated.

The problems we have listed so far have been strictly mechanical. But there are optical problems too. The optical system must present to the observer a normal, erect image, bright enough to be useful. The field of view must be reasonably wide, so the observer can find his target quickly.

The problem of image orientation is not hard. All you need are two prisms—one at the top of the tube and one at the bottom—facing in opposite directions.

Field of view is a harder problem. In one design the tube is 40 feet long; light enters it through a head window a trifle more than an inch wide. If there were no optical system in the tube except the two prisms, the field of view would be about one-tenth of one degree. But the optical system is so designed that the true field of the image will be around 30°.

Remember that all the light that forms the image must come through that small head window. So we must keep to a minimum not only the amount of glass in the system, but also the number of elements.

Another problem is incorporating some range measuring device into the periscope system itself. This is normally incorporated into the attack periscopes as a stadimeter. The stadimeter is the more important of the periscope's two ranging devices. The less important one being the telemeter, which is covered later in this chapter.

The periscope stadimeter uses the same principle as the hand-held stadimeter covered in Opticalman 3 & 2, NavPers 10205. It gives a double image, and has a built-in calculator. However, it contains no mirrors; it uses an entirely different system to give you a double image. You know that when the target and the eyepiece of a telescope are fixed, the image will move if you move the objective at a right angle to the axis. The periscope stadimeter uses this principle to displace the two parts of a double image. The objective lens of the lower main telescope is SPLIT VERTICALLY into two halves, with a small space between them.

To use the stadimeter, you first set the actual target height on the dial. Then, as you turn the ranging knob half the lower main objective rises (relative to the target image), and the other half is lowered. As a result, you will see a double image of the target, and the farther you turn the ranging knob, the farther the two images will separate. When you bring the top of one image into line with the bottom of the other, you can read the range on the stadimeter dial.

OPTICAL DESIGN OF THE SUBMARINE PERISCOPE

We will consider first the principal optical problem: securing a true field of useful width in spite of the small head window and the long narrow tube. The periscope designer solves the problem by combining simple optical systems such as the astronomical telescope.

An astronomical telescope produces an inverted image. It has only two principal elements—an objective and an eyepiece; this is a valuable feature for use in a periscope, since we are trying to hold the number of elements to a minimum. We need not worry about the inverted image if we use two astronomical telescopes in series. The first will invert the image; the second will reinvert it.

In any telescope, the magnifying power is equal to the focal length of the objective divided by the focal length of the eyepiece; and the magnifying power is equal to the apparent field divided by the true field. For example, suppose that an object, when viewed by the naked eye, subtends an angle of 5°. The same object, when viewed through a telescope, appears to subtend an angle of 30°. You know at once that the magnifying power of the telescope is 6 X.

Our problem is to take a fairly wide true field and reduce it to a narrow apparent field, so that the image will travel as far as possible down the periscope tube. You have probably looked through the wrong end of a telescope at some time or other. You remember that the objects you saw looked very small and far off (and consequently the true field of view was much larger than the apparent field).

The main optical system of the submarine periscope consists of two astronomical telescopes. We call them the UPPER MAIN TELESCOPE and the LOWER MAIN TELESCOPE. The upper main telescope is backwards—its eyepiece is at the top of the tube. Suppose we want a true field of 30°. And suppose that our upper main telescope has a magnifying power of 15 X—the focal length of its objective is 15 times that of its eyepiece. Since the upper telescope is backwards, its actual magnifying power will be 1/15 X, and its apparent field will be 1/15 the true field. Thus our 30° true field will be reduced to only 2° as it leaves the upper telescope, and that narrow beam can pass down the periscope tube for a considerable distance.

(In Opticalman 3 & 2, NavPers 10205, we defined the objective as the lens nearest the target. If we apply that definition to the upper main telescope of the periscope, then it is not really backwards. It is a normal telescope with a short-focus objective and a relatively long-focus eyepiece. But we are accustomed to working with telescopes whose magnifying power is more than one. We are used to the idea that the short-focus lens is the eyepiece, and the long-focus lens is the objective. The men who work with periscopes hold on to that idea—they call the upper lens of the upper telescope the eyepiece, even though there is no eye within 40 feet of it. We will go along with them. Keep that in mind so you will not be confused.)

The lower main telescope is in the normal position—its objective is toward the target, and the focal length of its objective is greater than that of its eyepiece. Its magnifying power, therefore, is greater than one. In the example given, we assumed that the upper main telescope had a magnifying power of 1/15 X. Now, if we give the lower telescope a magnifying power of 15 X, the magnifying power of the two together will be:

$$1/15 \times 15 = 1$$

The upper telescope reduced the true field of 30° to an apparent field of 2°. The lower telescope, with a magnifying power of 15 X, will bring the field back to an apparent field of 30°, equal to the true field of the instrument.

In figure 8-2 you can follow the path of light rays through the periscope we have described. Part A shows the action of the two telescopes alone; in part B we have added the two prisms, to bend the line of sight twice through 90°. In the figure, the broken line represents the optical axis. The two solid lines show the path of two rays from the center of the field; as they strike the first lens, they are parallel to the axis. The two dotted lines represent two diagonal rays, one from each extreme edge of the field. The angle between them is the true field of the instrument.

To illustrate the path of rays through an instrument, we can choose the rays that are most convenient for our purpose. We will use the two diagonal rays that cross in front of the upper eyepiece because those two happen to pass through the center of the upper objective. Since they pass through the objective without bending, the angle between them is the angle at which the light diverges as it leaves the upper telescope. These two rays limit the distance between the two telescopes—the objective of the lower main telescope must be close enough to the upper system so that these two rays will fall on it.

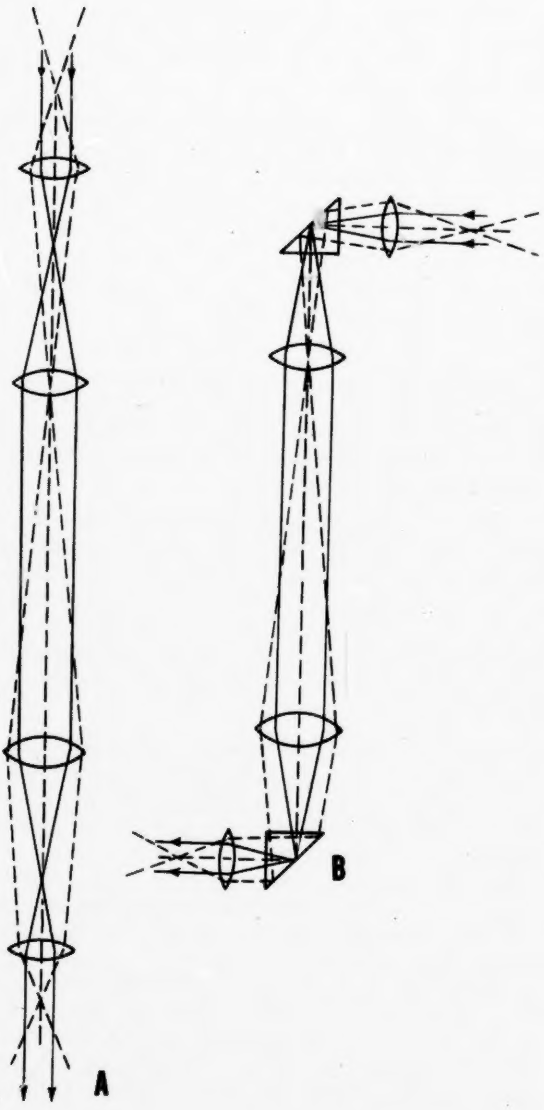

Figure 8-2.—Path of rays through a periscope.

As you can see in figure 8-2, there are two real images within this periscope. In part B of figure 8-2, we have put two real images at the reflecting surfaces of the prisms, simply because that makes it easier to follow the rays. You will not find this situation in an actual periscope, since any tiny flaw in the reflecting surfaces would show up as a part of the final image.

The sample periscope design we have described has a magnification of one. Since the magnifying power of the periscope is equal to the product of the separate magnifying power of its two telescopes, you can see that there are two ways to enlarge the image; we can decrease the reduction of the upper telescope, or we can increase the magnifying power of the lower telescope. We might decrease the reduction of the upper telescope from 1/15 to 1/7.5. Then the magnifying power of the whole system would be:

$$1/7.5 \times 15 = 2$$

Or, we could increase the magnifying power of the second telescope to 30 X. Then:

$$1/15 \times 30 = 2$$

The first method would require that we shorten the tube, since the rays from the first telescope would then diverge at an angle of 4°, rather than 2°. The second method would decrease the illumination of the system, since it would reduce the diameter of the exit pupil. Which method we would actually use would depend, of course, on what we wanted our design to accomplish.

Figure 8-3 shows how we can calculate the inter-objective distance between the two main telescopes. Part A of the figure shows the two objectives of the periscope in figure 8-2, and the path of the diverging rays between them. We want to calculate the distance L between the two objectives. Part B of figure 8-3 shows the triangle we will have to solve to find L. You can see that:

$$L = \frac{r}{\tan \theta}$$

Where L is the inter-objective distance, r is HALF the diameter of the objective of the lower telescope, and θ is half the apparent field of the upper telescope.

For a sample problem, let us use the periscope we have already described. The apparent field of its upper telescope is 2°. If the diameter of the objective of its lower telescope is 4 inches, what is the inter-objective distance? Substitute in the formula:

$$L = \frac{2}{\tan 1^\circ} \quad \frac{2}{.01746} = 114.5 \text{ inches}$$

The inter-objective distance of this periscope is about 9 1/2 feet.

To find the length of the entire optical system, we must add the length of the two telescopes. Theoretically we could make the telescopes any length, just by increasing the focal length of their objectives. But the APERTURE of the objectives is limited by the diameter of the tube. Therefore we cannot increase their focal length beyond certain practical limits without cutting the illumination below a useful level.

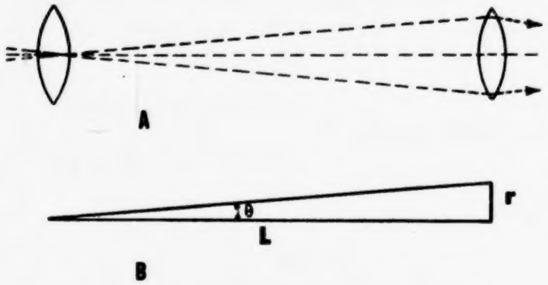

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Figure 8-3.—Calculation of the inter-objective distance.

In practice we have found that each telescope can be about the same length as the inter-objective distance without decreasing the illumination too seriously. So the total length of our periscope will be three times its inter-objective distance, or about 28 1/2 feet.

It is obvious that the design of any periscope is limited by several factors:

Length of the tube.
Diameter of the tube.
Magnifying power required.
Diameter of exit pupil.
Angle of true field.

Now suppose we have to design a periscope with the following characteristics:

Length of tube: not specified.
Diameter of tube: 5 inches.
Field: 40 degrees.
Thickness of tube walls: about 1/4 inch.
Exit pupil: 5 millimeters.
Magnifying power: between 1.2 X and 1.5 X.

We have only two variables to work with: the tube length (which is not specified), and the magnifying power (which must be between 1.2 X and 1.5 X). Now calculate the tube length for each of these two magnifying powers.

We will start by finding the magnifying power of the lower telescope. It is determined by two things: the aperture of its objective, and the size of its exit pupil. The inside diameter of the tube is 5 inches minus 1/2 inch, or 4 1/2 inches. The lens mount and its supporting tube will take up approximately another half inch, which limits the aperture of the objective to about 4 inches, or 101.6 mm. For convenience, let us call that 100 mm. Then what is the magnifying power of the lower telescope if the exit pupil is 5 mm? You remember that

$$\text{Magnifying power} = \frac{\text{diameter of objective}}{\text{diameter of exit pupil}}$$

Then:

$$M = \frac{100}{5} = 20 \text{ X}$$

Since the magnifying power of the finished periscope will be 1.2 X, the reduction in the upper telescope must be:

$$\frac{20}{1.2} = 16.67 \text{ X}$$

And since the true field of the periscope will be 40°, the apparent field of the upper telescope will be:

$$\frac{40^\circ}{16.67} = 2^\circ\ 24'$$

That is the angle at which rays diverge from the objective of the upper telescope. We can use that angle to calculate the inter-objective distance. The formula is:

$$L = \frac{r}{\tan \theta}$$

Where L is the inter-objective distance, r is half the objective aperture, and θ is half the apparent field of the upper telescope.

Substituting:

$$L = \frac{2}{\tan 1^\circ 12'} = \frac{2}{.02095} = 95.58 \text{ inches}$$

The inter-objective distance is approximately 7 feet 11 1/2 inches. The length of the whole system will be three times that, or [illegible] feet 10 1/2 inches.

You can see that all the characteristics of a periscope are interdependent. If we favor one of them we will have to sacrifice one of the others. The periscope we have designed is a rather short one. However, no length was specified. So if we want to, we can make it even shorter, and either increase the size of the exit pupil or decrease the diameter of the tube.

What will be the length of the specified periscope when its magnifying power is 1.5 X? The reduction of the upper telescope is:

$$\frac{20}{1.5} = 13.33$$

Since the true field is 40°, the angle of beam is:

$$\frac{40}{13.33} = 3^\circ$$

The inter-objective distance is:

$$L = \frac{2}{\tan 1^\circ 30'} = \frac{2}{.02619} = 76.37 \text{ inches}$$

$$= 6 \text{ feet } 4.4 \text{ inches}$$

and the length of the entire system will be three times that, or 19 feet 1.2 inches.

To increase the length of the tube beyond the limits we have calculated, we would have to add more telescope systems. To keep the image erect we could add one terrestrial telescope, or two astronomical telescopes, or one Galilean telescope. Of course, the addition of more telescopes is always objectionable, since it cuts down the illumination by reflection and absorption. However, there is often no other way in which we can design a periscope of the required length.

AUXILIARY TELESCOPES

In the longer periscopes such as the type 2 you will find two additional astronomical telescopes. We refer to them, respectively, as the UPPER AUXILIARY TELESCOPE and the LOWER AUXILIARY TELESCOPE. The two auxiliary telescopes are mounted above the main telescopes. Usually each of them has a magnification of one; their only function is to lengthen the system and to carry the image down through the narrow, tapered section at the top of the tube.

In all periscopes in service you will find a Galilean telescope at the very top of the optical system—above the upper auxiliary telescope. Since it is relatively short, it does not lengthen the tube too much. The Galilean telescope provides the periscope with its CHANGE-OF-POWER mechanism. Since it forms an erect image, it can be thrown in or out of the system without changing the orientation of the target image.

In practice, the submarine captain always uses the highest magnification of the periscope for measuring the range and bearing of his target, to aim his torpedoes. He will use the low power only for observation. Since the two lenses of the Galilean telescope are moved on or off the axis by a fairly long change-of-power control system, we cannot be sure they will always come to rest in exactly the same place on the axis. But in measuring target bearing, we must have maximum accuracy. We must, therefore, design the periscope to give low power with the Galilean telescope IN, and high power with the Galilean telescope OUT. We can do that by mounting the Galilean telescope backwards, like the upper main telescope. Its short-focus divergent lens will be toward the target; its long-focus convergent lens will be toward the observer.

Let us see how that actually works. In one typical periscope design, the high power is 6 X; the low power is 1.5 X. The Galilean telescope has a reducing power of 4 (or a magnifying power of 1/4 X). With the Galilean telescope OUT, of course, the power of the periscope is 6 X. With the Galilean telescope IN, the power of the periscope is:

$$1/4 \times 6 = 1.5 \text{ X}$$

TELEMETER LENS

The telemeter is one of the range-finding devices of the submarine periscope. It is essentially a reticle—a plano-convex lens with suitable markings engraved on its plane surface. The two auxiliary telescopes each add one real image to the periscope system. The engraved surface of the telemeter lens is mounted in the real image plane of the upper auxiliary telescope, and its markings therefore appear superimposed on the target image. The telemeter is placed in the upper auxiliary telescope so it will vibrate WITH the field of view, thus eliminating movement BETWEEN the telemeter and the target.

The markings on the telemeter lens appear on the image as horizontal lines, by which you can read the angular height of the target. (The value of the graduations depends, of course, on whether you are using high power or low power.) The telemeter system is similar in principle to a telescope with a mil scale engraved on its reticle. By observing the number of graduations that span the height of the target, you can read its angular height. Then, if you know its actual height, you can calculate its range by the formula

$$R = \frac{h}{\tan \theta}$$

Where R is the range in yards, h is the actual height of the target in yards, and θ is its angular height, as shown by the telemeter.

You can see that a submarine captain must be an expert in recognizing other ships, and he must know their dimensions by using the table of masthead heights. And you can also see that the telemeter never provides an instantaneous range reading; it always involves a calculation.

In ranging with the telemeter, the submarine captain always measures the angular HEIGHT of the target—never its angular LENGTH. The reason for this is that the angular length of a ship depends on its course angle. But the angular height, at any given range, is constant.

COLOR FILTERS

Like most of the Navy's larger optical instruments, the periscope has a color filter mount. It is located between the observer's eye and the lower eyepiece lens. (It is outside the eyepiece window, so it can be cleaned or repaired without breaking the gas seal of the periscope.) The colors are clear, yellow, red, and green. The polaroid filter can be attached to the color filter mount, so that, if necessary, you can use it in combination with one of the colors. When not in use, the polaroid filter can be attached to the eyepiece box end of the periscope itself.

PRINCIPAL COMPONENTS OF THE TYPE 8B PERISCOPE

The submarine periscope system 8B is a general purpose instrument consisting of a type 8B periscope, an Electrical and Electronic (E and E) Adapter, and several externally mounted control or connection boxes.

The type 8B periscope is a night service instrument of 36-foot optical length and 7 1/2-inch outer diameter, exclusive of the eyepiece and faceplate assembly, handles, and other controls on the eyepiece box. All electrical connections to the periscope are made through the E and E adapter.

The optical system in the 8B periscope contains a tilting head prism that is capable of elevating the line of sight 60° above the horizontal, and 10° below the horizontal. A sun filter located in the head section may be moved in or out of the optical path while the periscope is in high power. At night the telemeter may be red-illuminated for better observation. There are also attachments provided for mounting a camera adapter to the eyepiece box for taking photos while the submarine is submerged.

The 8B periscope also contains a means of de-fogging and de-icing the head window of the periscope by use of a heated head window.

The men on submarines at times have to stand watch at the periscope when the submarine is submerged. To make this job a little easier the periscope system incorporates a training torquer, which is operated from the right training handle and is used to aid in training the periscope. This is done by use of a motor, which when turned on will help turn the periscope. After about 15 minutes on watch, having to turn the periscope by hand would wear the man out. With the power torquer to assist him, this will not happen. The power torquer is to be used as an assist to help turn the periscope and is not to be used alone. If used correctly, it will be like using power steering in a car.

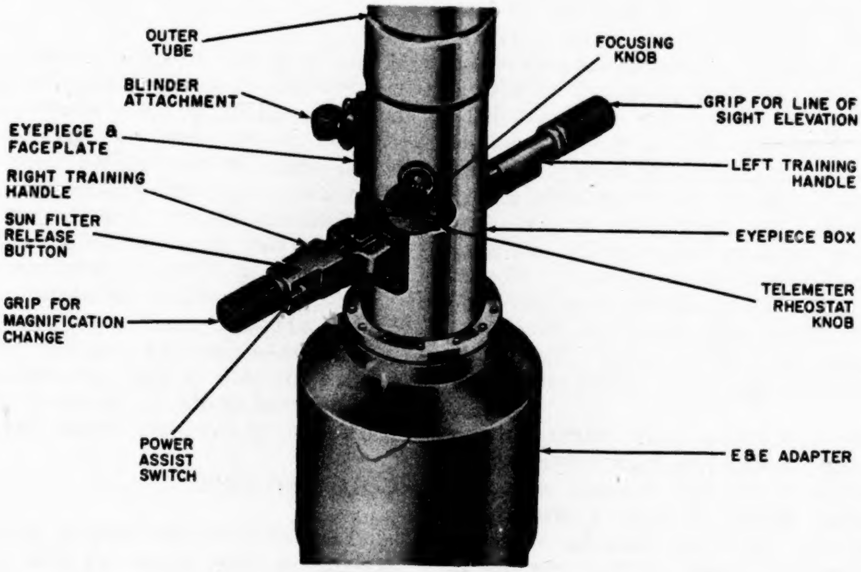
OUTER TUBE
BLINDER ATTACHMENT
EYEPIECE & FACEPLATE
RIGHT TRAINING HANDLE
SUN FILTER RELEASE BUTTON
GRIP FOR MAGNIFICATION CHANGE
POWER ASSIST SWITCH
FOCUSING KNOB
GRIP FOR LINE OF SIGHT ELEVATION
LEFT TRAINING HANDLE
EYEPIECE BOX
TELEMETER RHEOSTAT KNOB
E&E ADAPTER

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Figure 8-4.—Eyepiece box.

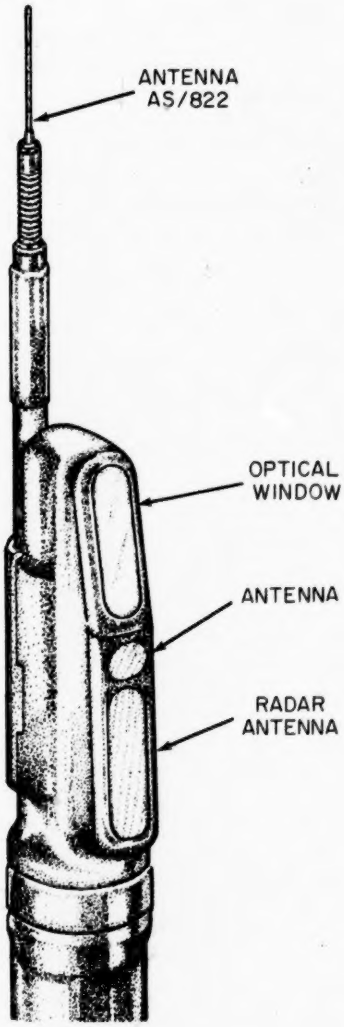

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Figure 8-5.—Head section.

EXTERNAL CASING

The external casing of the periscope system consists of four main sections: the outer head, the outer tube, the eyepiece box, and the E and E adapter. The joints between the outer head and the outer tube and between the outer tube and eyepiece box, consist of an "O" ring, a bronze coupling, two setscrews, and a gasket seal. The outer tube itself is made out of corrosion-resisting steel.

INTERNAL FRAMEWORK

The internal framework of the system consists of three main parts: the head skeleton, the body skeleton, and the eyepiece components. All of the internal optics are supported and positioned by this framework. The shafts and linkages from the eyepiece box, which are used to operate the mechanisms, are also supported by the internal framework.

OPTICAL SYSTEM

The optical system of the 8B periscope consists of three main components: the head assembly, optical relays, and the eyepiece and faceplate assembly. The head assembly contains a tilting prism, which is operated by rotating shafts and gearing from the left training handle. A 2-speed and a 36-speed synchro are also incorporated, for precision measurement of the relative elevation of the line of sight.

For low-power operation, movement of the right training handle mechanically causes two lenses (Galilean cubes) to rotate into position just below the head prism. These lenses act as a reverse telescope to decrease the periscope magnification.

When the periscope is in the high power operating position, further movement of the right training handle causes a sun filter to rotate into place. The focusing knob on the side of the eyepiece box, shown in figure 8-4, mechanically moves the focusing erector lens near the base of the tube. This knob provides for the +1.5 to - 3.0 diopter focus range for the observer, and also provides for camera focus. There is also a sextant switch located on the left training handle, for taking sextant readings while submerged.

HEAD SECTION

Information on various components of the head section is not included in this course because it is classified. Figure 8-5 shows the head section.

The following are the design characteristics for the 8B periscope:

Weight	1,537 pounds
Outer diameter of main tube	7.497 inches
Overall length of periscope with model F621 stub antenna	39 feet
Optical length of periscope	36 feet
Magnification:	
High power	6 X
Low power	1.5 X
True field of view:	
6 X	8°
1.5 X	32°
Exit pupil diameter 6 X and 1.5 X	7 mm
Maximum elevation, line of sight	60°
Maximum depression, line of sight	10°

CHAPTER 9

PERISCOPE MAINTENANCE AND REPAIR

This chapter describes the general maintenance procedures you will use most often on the submarine periscope, and the procedure for removing the periscope from the submarine and transferring it to the optical ship. Detailed information on the submarine periscope is classified and is not included in this course. You will find that information in the Maintenance Technical Manual Submarine Periscope Type 8B and 8C, NavShips 324-0447.

HANDLING AND STORAGE

A modern submarine periscope, in spite of its size (up to 50 feet in length) and weight (up to 2,000 pounds) is a fragile instrument. When moving it from one place to another, be constantly alert to protect it from bending, vibration, or shock. Periscopes are shipped and stored in sturdy boxes, and are secured by clamps. These clamps prevent endwise movement within the box.

When you remove a periscope from its box, be sure to put the clamps back in the box so they can be used again. When returning a periscope to its box for reshipment, be sure that all the clamps are in place. See that all accessories are either mounted on the periscope itself, or carefully secured inside the box.

When moving a periscope in its box, always hoist or support the box at more than one point—preferably at the quarter points--to prevent needless stresses on the periscope tube. If a periscope is shipped by rail, the box should be securely chocked in the car. For highway shipping a reach truck should be used if available. The box should be so loaded on the truck that the overhanging end contains the upper, lighter end of the periscope. The nameplate of the shipping box should always be at the heavy end.

FOGGING OF OPTICAL SURFACES

Maintenance of the installed periscope is limited almost entirely to elimination or prevention of fogged optical surfaces. All windows, cover plates, and input shafts must be kept watertight and gastight. Gas pressure within the periscope must be maintained at 7 1/2 pounds per square inch (psi) at 70° F, to prevent all possibility of "breathing" when the pressure changes. (Pressure will vary from 7.1 psi at 60° F to 7.9 psi at 80° F. The pressure will vary even more at extreme temperatures.) The gas used for charging the instrument must be so dry that no condensation can occur at any temperature that the periscope may conceivably encounter in service.

Fogging inside the periscope can be prevented by keeping the dewpoint of the charging gas extremely low. Since there is no control possible over the dewpoint of the air outside the periscope, fogging of the external surfaces is fairly common. Fortunately, it is easy to correct.

The bottom of the periscope well is likely to be considerably colder than the air in the conning tower. When the periscope is raised to the observing position, especially if the air in the submarine is fairly humid, condensation may occur on the eyepiece window, and sometimes on the color filters. The observer's breath sometimes causes condensation on these surfaces. The fogging usually disappears after the periscope has warmed up for a few minutes. If it does not, it may be necessary to open the color filter housing, to let the air circulate freely inside. In stubborn cases, remove the color filters and wipe the eyepiece window with lens tissue. The type 8B has a heater, which will keep the eyepiece from fogging up, and a device which heats up the head window to prevent fogging.

External fogging of the head window is much less likely, though it may occur if the

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temperature of the sea water is below the dewpoint of the air at the surfaces. If when the periscope is first raised, the image is clear, but clouds up a few minutes later, moisture is probably condensing on the head window as it dries. To correct this condition lower the periscope far enough to wet the head window, and then raise it again.

INTERNAL FOGGING

Internal fogging is far more serious than external fogging, and of course it is much easier to prevent than to correct. Prevention requires only that all fittings be airtight, and that the instrument be kept fully charged with very dry nitrogen. If internal fogging does occur, the periscope must be dried out by a process called CYCLING. An outline of the cycling procedure is:

1. Slowly charge the periscope to high pressure (about 100 psi for scopes sealed with gaskets and 50 psi for scopes sealed with "O" rings). (Never look in the periscope while it is being charged.)
2. Test for leaks by coating all fittings with soapsuds.
3. Release the pressure, and draw a low pressure vacuum (about 2 mm of mercury).
4. Close valves, and maintain the vacuum for 3 hours. If the pressure rises noticeably, redraw the vacuum; continue until the periscope can hold its vacuum for 3 hours. (A rise in pressure is not necessarily due to a leak; it may be due to water vaporizing inside the periscope.)
5. Charge with dry nitrogen to 10 psi; then bleed to 7 1/2 psi.

You can cycle and recharge the periscope without removing it from the submarine, PROVIDED THE TEMPERATURE IS 50° F OR HIGHER. At temperatures below 50° F, the vapor pressure of water is too low to permit thorough drying. If you have to cycle a periscope when the temperature in the submarine is below 50° F, remove the periscope and take it to the optical shop.

When is it necessary to cycle the periscope? Follow these rules:

1. Each time a periscope is dried and recharged, attach a tag to show the date and pressure of recharging. When inspecting the instrument, check the date on the tag. If the periscope has not been recharged in the preceding 6 months, check the scope and recharge it if necessary.
2. If submarine personnel report that the periscope is fogging, and the fogging is found to be INTERNAL, cycle the instrument and recharge it.
3. Each time the periscope is disassembled or overhauled, or when the gas seal is broken for any reason, the instrument must be cycled and recharged.
4. When inspecting a periscope, carefully measure the pressure of its charging gas. (Attach a gage to the outlet connection even if the periscope has a built-in pressure gage.) If the test shows a pressure of 4 psi or less, cycle and recharge. (f the pressure is between 4 and 7 1/2 psi, charge to 10 psi with nitrogen (dried by a silica-gel dryer or by the cold trap method) and then bleed to 7 1/2 psi.
5. If it is convenient, make a dewpoint test of the charging gas when inspecting the periscope. (The dewpoint test is described later in this chapter.) The dewpoint of the charging gas should be -50° C or less. If the dewpoint of the charging gas is appreciably higher than that, cycle and recharge.

Every periscope in service is provided with at least one inlet/outlet connection, controlled by a valve. And each periscope is provided with some means for ensuring circulation of the drying gas within the instrument. In many designs, the gas passes through the inlet valve (which is always at the bottom of the instrument), through a charging pipe, to the head section. From the head section it passes downward through the optical tube and external casing to the outlet valve. In other periscopes the gas passes upward through the optical tube to the head section, and then downward in the space between the optical tube and the external casing.

CHARGING GAS

The drying and charging gas for submarine periscopes is NITROGEN, prepared in accordance with Navy specifications. The specifications require that the nitrogen be delivered in cylinders charged to 1,800 pounds per square inch. The nitrogen must be entirely free from acid, dust, and objectionable impurities, and it must be at least 99.5 percent pure. CAUTION: DO NOT USE A CYLINDER AFTER ITS PRESSURE HAS FALLEN BELOW 400 psi. (When pressure in a cylinder is below 400 psi, oil and dirt in the bottom of the cylinder will be discharged into the periscope.)

DRYING EQUIPMENT

In drying or charging a periscope, the gas from the cylinder must pass through a special drying device before it enters the periscope. Either of two drying devices can be used. The most reliable of these is the COLD TRAP. It consists of a coil of tubing immersed in a bath of acetone and dry ice. The temperature of the cooling mixture will be around -70° C or less. Any moisture in the drying gas will condense on the inside walls of the copper tubing, until the dewpoint of the gas is reduced to the temperature of the coil. The gas that emerges from the cold trap is extremely dry.

Dry ice can usually be made aboard a repair ship or tender with the help of a Snow Man, if you have one. The Snow Man is a small, compact, automatic machine, which makes dry ice from carbon dioxide gas. From one 50-pound cylinder of CO_2 gas, the Snow Man will make about ten 12-ounce cakes of dry ice.

If neither dry ice nor the means of making it is available, use a SILICA-GEL DRYER. Figure 9-1 shows a Mk 3 instrument dryer modified for use with the submarine periscope. Note the filter units inside the cylinder, and the Cuno Filter in the outlet line.

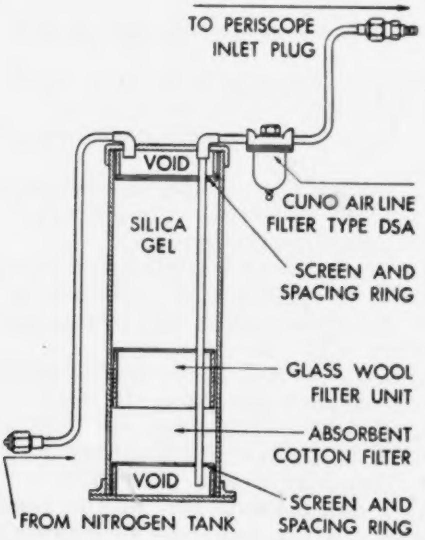

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Figure 9-1.—Mk 3 instrument dryer, adapted for periscope use.

Since the indicator crystals are not sufficiently reliable to show the condition of the silica gel, the gel must be baked immediately before each use, regardless of the color of the indicator crystals. Use a covered pan or kettle; bake for 2 hours at a temperature of 500° F.

Silica gel tends to be dusty, the purpose of the filters in the dryer and its outlet line is to keep the dust from entering the periscope. Even so, some dust may pass through. This is extremely objectionable, since dusting off one of the internal surfaces of a periscope is a major operation. So whenever it is possible use the cold trap rather than the silica-gel dryer.

DEWPOINT TEST

The dewpoint of a gas is tested by letting the gas flow against a cold surface and gradually reducing the temperature of the surface until moisture condenses on it. When condensation begins, the temperature of the surface is equal to the dewpoint of the gas.

Figure 9-2 shows the equipment required for a dewpoint test. The numbers in the figure correspond to those listed here:

1. A centigrade thermometer, with a range from minus 100° C to plus 50° C.

2. Three 200-ml pyrex Erlenmeyer flasks, each silvered on the bottom and part of the side. If the silver is outside, it must be copper plated and coated with acetone-resisting enamel. If the silver is inside, it must be coated with clear lacquer.

3. Two pieces of glass tubing (total about 12 inches), bent to form an inlet and outlet tube as shown in the figure.

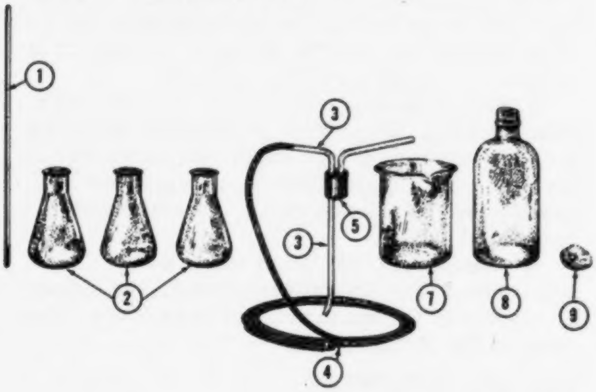

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Figure 9-2.—Dewpoint testing equipment.

4. Four feet of rubber tubing.
5. A two-hole rubber stopper to fit the Erlenmeyer flasks, and hold the inlet and outlet tubes.
6. Half a pound of dry ice. (Not shown.)
7. A one-liter pyrex beaker, big enough to contain one of the Erlenmeyer flasks immersed in 2 inches of cooling mixture.
8. Half a liter of acetone.
9. Soft apiezon wax, for sealing the fittings.

To make a dewpoint test, follow these steps:

1. Heat the Erlenmeyer flasks on a hotplate to drive out all moisture.
2. Assemble one of the flasks with the rubber stopper, the inlet and outlet tubes, and the rubber tubing. The inlet tube should almost touch the bottom of the flask. (Leave the two other flasks on the hotplate to keep them warm and dry.)
3. Connect the rubber tubing to the outlet connection of the periscope. Use the soft apiezon wax to seal all the connections: one at each end of the rubber tubing, two at the top of the rubber stopper, one between the stopper and the flask.
4. Open the periscope outlet valve very slightly, to permit an extremely light flow of gas through the apparatus. To detect a light flow of gas, hold the outlet tube of the flask close to your lips. If the escaping gas can be felt with your finger, the flow is too strong.
5. Pour the half-liter of acetone into the beaker.
6. Immerse the Erlenmeyer flask in the acetone, to about an inch above the silvered sides. Try to keep the flask from touching the bottom of the beaker.
7. Put the thermometer into the acetone, and hold it or clamp it so that its tip is about 1/4 inch from the bottom of the beaker. (If the thermometer touches the sides or bottom of the beaker, it will give a false reading.)
8. Slowly add powdered dry ice to the acetone, stirring constantly. Carefully watch the silvered surface of the flask, under the end of the inlet tube. When the surface begins to cloud, quickly read the thermometer. Record the temperature.
9. Repeat the test twice more, using the two other warm, dry Erlenmeyer flasks. The highest of the three thermometer readings is the dewpoint of the charging gas.

CYCLING EQUIPMENT

Figure 9-3 shows some of the equipment needed for cycling a periscope. The numbers in the figure correspond to those listed here, except as noted:

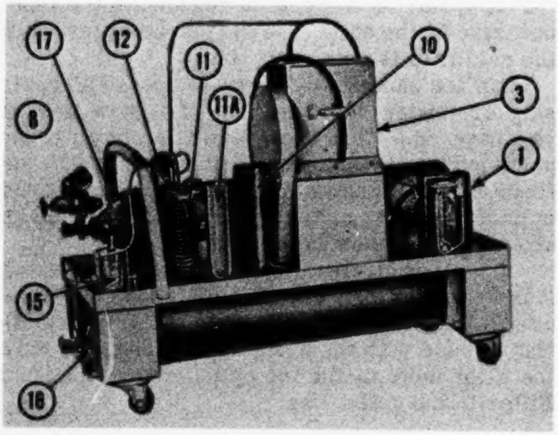

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Figure 9-3.—Cycling equipment.

1. A vacuum gage (Stokes-Flosdorf Manometer).
2. Vacuum gage fitting for the inlet connection of the periscope. (Not shown.)
3. Cenco Hyvac pump.
4. Cenco Hyvac pump fitting for the outlet connection of the periscope. (Not shown.)
5. A pressure gage, with a range from zero to 150 psi. (Not shown.)
6. A Mk 3 instrument dryer, adapted for use with the periscope (as in fig. 9-1).
7. Freshly baked silica gel. (Not shown.)
8. Reducing valve for the nitrogen cylinder.
9. Soft apiezon wax. (Not shown.)
10. Pyrex thermos jar, with an inside diameter of 2 3/4 inches, and an inside depth of 12 inches. The thermos jar should be surrounded with half-inch cork insulation, and secured in a metal container. The joint between the insulation and the flask should be sealed with wax.

11. Fifteen feet of 3/8-inch copper tubing, coiled to 2 1/2 inches outside diameter, and inserted in the flask.

11A. Wire screen.

12. A Cuno air filter, in the line between the nitrogen tank and the copper coil.

13. Half a liter of acetone. (Not shown.)

14. Three pounds of dry ice. (Not shown.)

15. Snow Man dry ice machine.

16. Cylinder of CO_2.

17. Nitrogen cylinder.

The above list includes all the equipment for BOTH methods of drying. If using the cold trap method, you will not need items 6 and 7. If using the silica-gel dryer, you will not need items 10, 11, 13, 14, 15 and 16. Remember: DO NOT use the silica-gel dryer unless the cold trap method is impracticable.

CYCLING PROCEDURE

If inspection of the periscope has shown that cycling and recharging are necessary, follow these steps:

1. Carefully measure the temperature in the conning tower of the submarine and the temperature of the outside air. If either is below 50° F, remove the periscope and take it to the optical shop for cycling.

2. If conditions are satisfactory for cycling aboard the submarine, elevate the periscope from its well—high enough to give easy access to its inlet/outlet connection. Be sure all required equipment is aboard the submarine. Do not try to run in long vacuum or pressure lines from outside.

3. Turn the stadimeter handwheel to the observing position, as shown by the stamped numerals on the stadimeter housing. To ensure easy reassembly of the stadimeter, set the number 58 on the height scale dial opposite the value 2.2 on the range scale dial. (In periscopes with no course-angle scale, set the number 15 on the height scale dial opposite the value 220 on the range scale dial.) Remove the four bolts from the stadimeter housing and lift off the stadimeter assembly, working carefully so as not to bend the transmission shaft. (The stadimeter will be found on attack scopes only.)

4. Remove all the other external projection fittings from the eyepiece box, including the training handles, the focusing knob, and the color filter attachment. This will give access to all the packing glands, so you can test them for leakage.

5. Remove the outlet plug of the periscope, and release the internal gas pressure, if any, by opening the air outlet valve. When all the pressure is released, close the outlet valve.

6. Remove the inlet plug, and secure the hose fitting in the inlet connection.

7. Insert the zero to 150 psi gage in the air outlet fitting and use an offset screwdriver to open the outlet valve, as in figure 9-4.

8. Connect the nitrogen cylinder, through the reducing valve and the dryer, to the inlet connection of the periscope. If you are using the cold trap dryer, pour half a liter of acetone into the flask, and stir 3 pounds of powdered dry ice into the acetone. Run gas slowly through the dryer and charging lines for about a minute before making the connection to the periscope.

9. Close the reducing valve on the nitrogen cylinder. Open the main valve, and set the reducing valve for a pressure of 10 psi. Then open the inlet valve of the periscope.

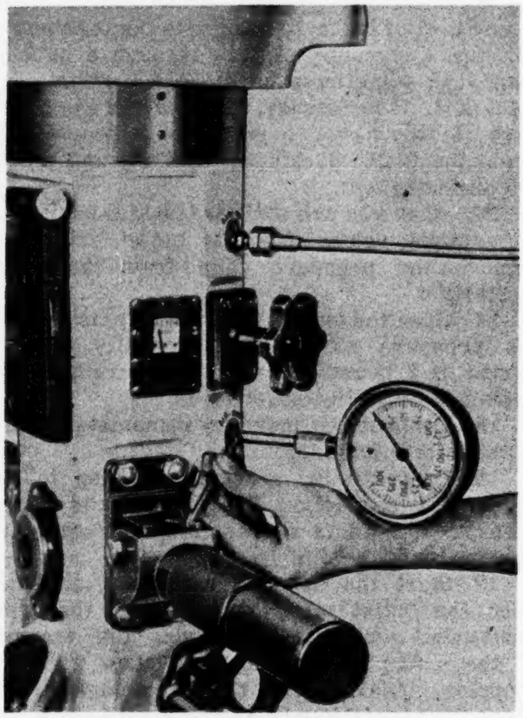

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Figure 9-4.—Opening the outlet valve.

10. Slowly build up the pressure. Remember that strong gas currents in the periscope may deposit dust on the optical surfaces, and a sudden increase in pressure may throw the optical system out of line. Raise the pressure in 4-pound steps, holding each value for about 5 minutes before increasing it. The pressure should build up to 100 psi (50 psi for scopes sealed with "0" rings) in about 2 hours.

11. When the gage in the outlet connection shows a pressure of 100 psi, close the inlet valve of the periscope. Close off the nitrogen pressure at the cylinder, and remove the charging line fitting from the periscope inlet connection.

12. Now check the periscope for leaks. If possible submerge the entire lower end, including the whole eyepiece box, in a container of water. If that is not possible, coat all connections and packing glands with heavy soapsuds, and watch for bubbles. At the periscope head, soap the edge of the window, the bezel frame screwheads, the gasket, the connection between the head and the taper section, and the bolts that secure that connection. If there is any sign of leakage, eliminate the leak before drawing a vacuum. A leak through a packing gland can sometimes be stopped by tightening the gland. If necessary, release the gas pressure (slowly, over a period of 2 hours), replace the faulty packing or gasket, and repeat the pressure test.

13. When you are satisfied that the periscope is gastight, close the air outlet valve and remove the pressure gage from the outlet connection.

14. Open the outlet valve slightly, to release the pressure slowly and gradually over a period of 2 hours. When all pressure has been released, close the outlet valve.

15. Connect the mercury manometer fitting to the inlet connection.

16. Connect the evacuating fitting to the air outlet connection. Keep all leads short, with as few joints as possible, to reduce the possibility of leakage.

17. Start the Cenco Hyvac pump, and then open the outlet valve. Do not leave the pump unattended while it is drawing the vacuum. If the pump should stop, or show signs of stopping, quickly grab the hose, kink it, and close the air outlet valve to prevent the periscope vacuum from drawing air back through the pump. The air that is drawn back will carry oil and oil vapor from the pump into the periscope and deposit it on the optical surfaces. It takes a major overhaul to repair this damage.

18. When the pump is operating properly open the inlet valve, so the manometer can indicate the vacuum in the periscope. Keep pumping until the manometer shows a pressure of 4 mm or less (2 mm, if it is possible to pump it down that low). Then close the outlet valve, and secure the pump.

19. Hold the vacuum for 3 hours, and then read the manometer. Any rise in pressure shows that drying is incomplete, and so will require more pumping.

IMPORTANT: if you continue pumping, start the pump and let it run a few seconds BEFORE opening the outlet valve.

20. When the periscope will hold a vacuum, close both the inlet and outlet valves, and disconnect the pump and manometer.

21. Now the periscope is ready for charging. Run nitrogen through the dryer and connecting lines for a few seconds, then connect the line to the input fitting of the periscope. If a cold trap dryer is being used, add more dry ice to the acetone, to bring the mixture up to the top of the coil.

22. Insert the pressure gage in the air outlet connection, and open the outlet valve.

23. Slowly open the inlet valve, and gradually build up the pressure to 10 psi. Then close the inlet valve, and shut off the nitrogen pressure at the cylinder. Disconnect the nitrogen inlet fitting, and replace the inlet plug.

24. Close the outlet valve, and remove the pressure gage. Connect the dewpoint test apparatus to the outlet fitting, and a dewpoint test. If the dewpoint is higher than minus 50° C, you must repeat the cycling procedure from the beginning.

25. If the dewpoint is satisfactory, bleed the pressure VERY SLOWLY, through the outlet valve, to 7 1/2 psi. If the periscope has a built-in gage, this is easy. If it does not have a built-in gage, bleed a small amount of gas, close the outlet valve, insert the gage in the outlet connection, open the valve, and read the gage. Then close the valve, remove the gage, and continue bleeding, with frequent pressure checks, to 7 1/2 psi.

26. The cycling procedure is now complete. Secure all the cycling equipment. Replace the outlet plug, and all the external fittings of the periscope.

SAFETY PRECAUTIONS DURING CYCLING

Here is a list of safety precautions to remember and observe during cycling:

1. Never let the periscope vacuum draw air back through the pump.
2. Use a reducing valve to lower the pressure of gas from the charging cylinder.
3. When using a silica-gel dryer, bake the silica-gel for 2 hours at 500° F, immediately before use. Do not rely on the color of the indicator crystals.
4. Be sure that the filter in the charging line is clean and tight.
5. Be sure that all connections are tight.
6. Bleed out all lines before charging the periscope.
7. Never try to cycle a periscope at a temperature below 50° F.
8. Be sure the periscope is tight before releasing the pressure. A proper vacuum can never be drawn on a leaking periscope.
9. Always take the dewpoint test from the air outlet connection of the periscope—never from the inlet connection.
10. Always charge the periscope slowly, building up the pressure gradually. In building up the 100 psi pressure (50 psi for scopes sealed with "O" rings) always take a full 2 hours, and take another 2 hours to release it.
11. Never use a nitrogen cylinder after the pressure has dropped to 400 psi or less.
12. To ensure a complete seal, use spiezon soft vacuum wax around the hose fittings of the inlet and outlet connections.

CARE OF A FLOODED PERISCOPE

Occasionally the head or head window of a periscope will be broken by striking some object in the water, or by the shock of depth charging, and the periscope will fill up with sea water. It is essential that no time be lost in removing salt water from the periscope, as corrosion damage begins almost immediately. In the event of flooding the following procedures are recommended:

1. As soon as possible after flooding, the periscope should be drained of sea water and flushed with fresh water. This can be accomplished by removing the head window and providing a means of drainage and venting of trapped air at the bottom of the periscope. Providing an access for drainage may be accomplished in a number of ways, depending on the periscope involved.

On Type 2A periscopes: (Reference NAVSHIPS 324-0293) Remove the stadimeter housing to gain access to the eyepiece skeleton retaining screw. Remove the retaining screw and lead washer to permit drainage.

On Type 8 periscopes: (Reference NAVSHIPS 324-0292) Remove the bottom eyepiece flange to gain access to the eyepiece skeleton retaining screw. Remove the retaining screw and lead washer to permit drainage.

On Types 2D, 2E, 2F, 8B, 8C, 8D, and 8L periscopes: (Reference NAVSHIPS 324-0487, 0515, 0442) Remove down to E & E adapter on 8B, 8C, and 8L periscopes to prevent entrance of water when the periscope is being flushed. Remove and/or loosen the lower door sufficiently to permit drainage.

Prior to flushing, movable optical components, such as the Galilean lenses and stadimeter lens, should be moved aside. Also, the head prism should be rotated to provide maximum clearance for the stream of water and/or filling hose. A large volume of fresh water directed as a gentle stream through the head window opening is preferable to a high pressure stream from a nozzle.

2. After all sea water has been drained and the periscope flushed thoroughly, seal the drainage hole and permit the scope to fill with fresh water. Actuate the operating controls a number of times to permit the fresh water to enter all possible areas. Prevent the entrance of additional sea water if possible.
3. The flooded periscope should be returned to an optical repair facility as soon as possible for overhaul.

REMOVING A PERISCOPE

To remove a periscope from a submarine and transport it to the optical shop of a tender, follow these steps:

1. Removing a periscope from a submarine can be done only in a sheltered harbor, since rolling of either ship is likely to seriously damage the periscope. The submarine should be moored alongside the tender on the side from which it will be easiest to move the periscope into the optical shop. If there is a cover plate over the steady bearing of the submarine (at the top of the periscope opening), remove the plate.

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2. Elevate the periscope high enough to attach the slings. You will need free access to at least 2 feet of the outer tube below the point where the taper section is joined to it.

3. Bolt a forged steel hoisting clamp around the outer tube, at least 12 inches below the joint between the outer tube and the taper section. (The hoisting clamp is marked No. 2 in fig. 9-5.) The hoisting clamp should be lined with emery cloth with its smooth side next to the outer tube of the periscope. Since the friction between the clamp and the outer tube must support the weight of the periscope, do not try to use a clamp that fits poorly. And never use a clamp containing setscrews. Bolt one or two safety clamps (No. 3 in fig. 9-5) to the outer tube above the hoisting clamp. The safety clamps will keep the periscope from slipping downward within the hoisting clamp.

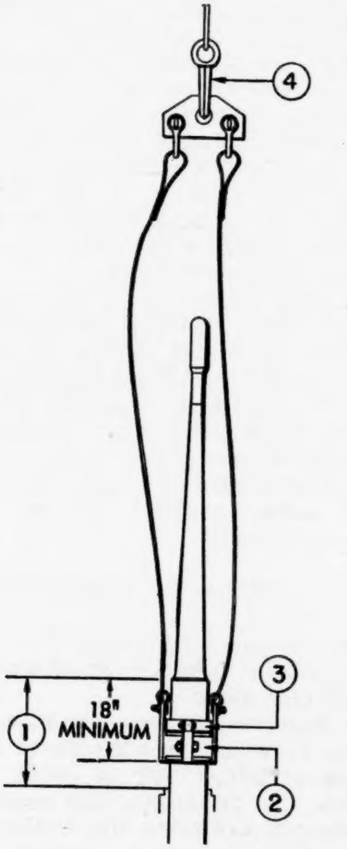

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Figure 9-5.—Clamps and slings attached to the outer tube.

4. The slings must be long enough to clear the periscope head, and they must be attached to a spreader bar of sufficient width to keep them from fouling the head. Put the hook of the lifting crane in the hook opening of the spreader bar, as in figure 9-5.

5. Raise the periscope to observing position, and transfer its weight to the lifting crane.

6. Now remove all parts of the periscope that project beyond the diameter of the outer tube. Figure 9-6 shows these parts. First, remove the two training handles by removing the four hinge bracket bolts.

7. Remove the focusing knob assembly by taking out four lockscrews.

8. Remove the color filter assembly by pulling outward on the two spring-actuated plunger knobs.

9. Remove the stadimeter housing. (Follow the directions given earlier in this chapter.)

10. Remove the eyepiece attachments, which are secured to anchor screw pins projecting from the eyepiece box.

11. Now check to be sure the lifting crane is holding the weight of the periscope. Slack off the hoisting yoke.

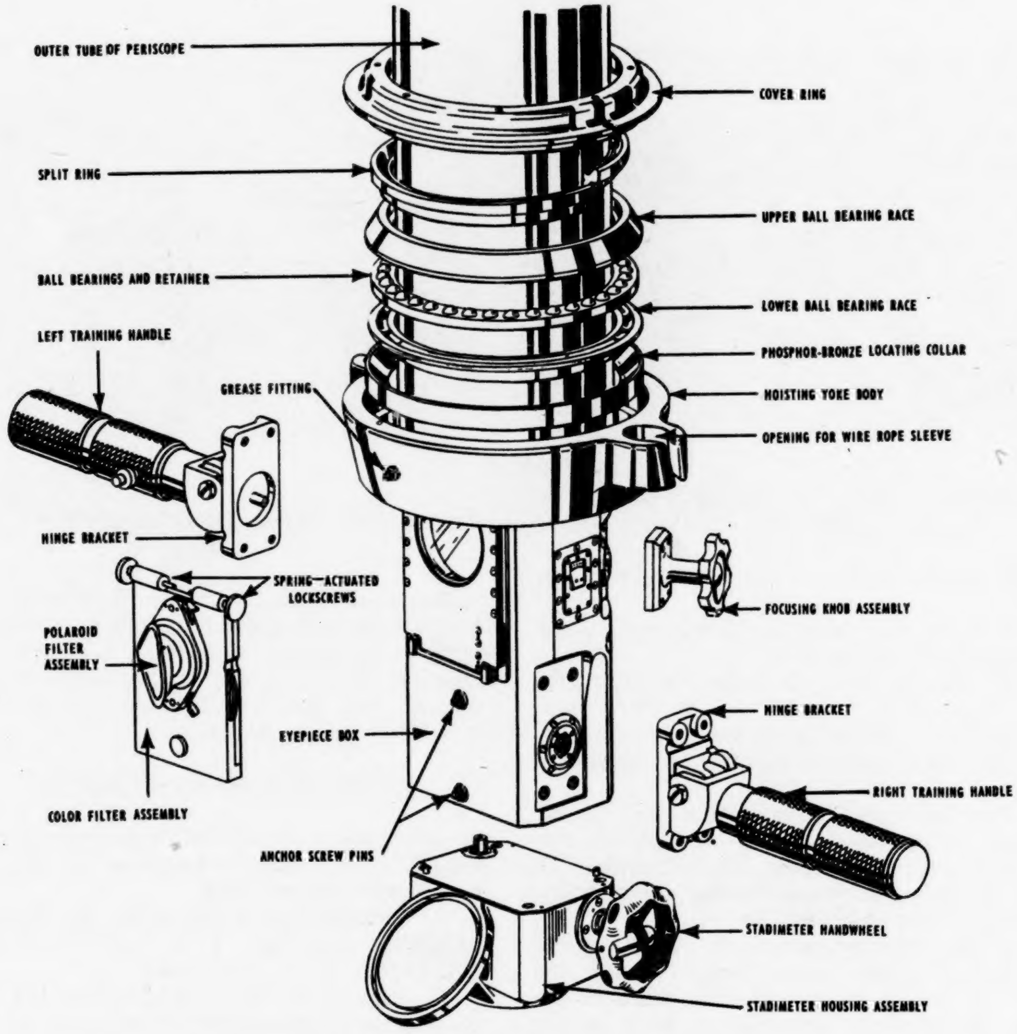
12. Remove the lockscrews from the cover ring, and unscrew the cover ring with a spanner wrench. Then remove the hoisting yoke body, the phosphor bronze locating collar, the lower ball bearing race, the ball bearings and retainer, and the upper ball bearing race. (These parts are identified in fig. 9-6.) Be especially careful to protect all these parts from dirt and grit.

13. Remove the split ring and the ring cover.

14. Slack off the hull stuffing box gland.

15. The periscope must be hoisted vertically; before hoisting, check to be sure that the crane boom is directly above the periscope. Attach a hinged clamp with handles to the outer tube above the deck opening of the submarine. While the crane is hoisting the periscope, use the handles of the clamp to rotate the periscope back and forth, to be sure it is not binding. If there is any tendency toward binding, stop hoisting at once, and do not start again until you have found the trouble and corrected it.

16. Hoist the periscope clear of the submarine and transport it in a vertical position


OUTER TUBE OF PERISCOPE
COVER RING
SPLIT RING
UPPER BALL BEARING RACE
BALL BEARINGS AND RETAINER
LOWER BALL BEARING RACE
LEFT TRAINING HANDLE
PHOSPHOR-BRONZE LOCATING COLLAR
GREASE FITTING
HOISTING YOKE BODY
OPENING FOR WIRE ROPE SLEEVE
HINGE BRACKET
SPRING—ACTUATED LOCKSCREWS
FOCUSING KNOB ASSEMBLY
POLAROID FILTER ASSEMBLY
HINGE BRACKET
EYEPIECE BOX
RIGHT TRAINING HANDLE
COLOR FILTER ASSEMBLY
ANCHOR SCREW PINS
STADIMETER HANDWHEEL
STADIMETER HOUSING ASSEMBLY

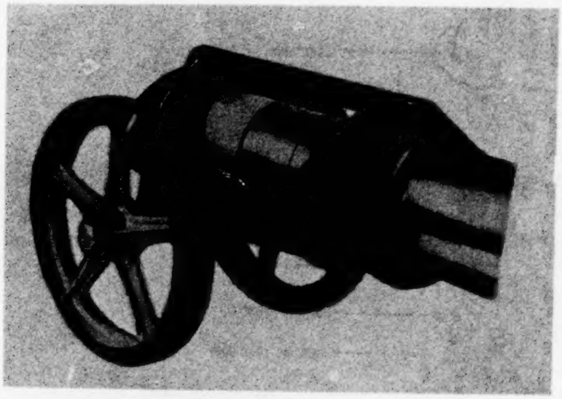
148.101

Figure 9-6.—External parts to be removed from the periscope.

to the upper deck of the tender. To place the periscope in a horizontal position on the deck, first secure the lower end in a hinge carriage (see fig. 9-7). Roll the carriage under the periscope, and turn it so that its clamp section is vertical. Lower the periscope into the clamp opening of the carriage, to within 4 inches of the deck. Line the clamp and cap with emery cloth, with the smooth side toward the outer tube of the periscope. Close the clamp cap and bolt it to the clamp section of the carriage.

17. Slowly lower the periscope toward a horizontal position, rolling the hinge carriage (which carries the weight of the lower end of the periscope) in the proper direction along the deck. Figure 9-7 shows the hinge carriage, and the lower end of the periscope, in horizontal position.

18. When the periscope is nearly horizontal move the clamp carriage into position under it, with the upper half of the clamp hinge open. Lower the periscope into the clamp; close upper half of the clamp, and secure



148.102
Figure 9-7.—Hinge carriage at horizontal position.

it with the swinging wing nut. (See fig. 9-8.)

19. Remove the hoisting clamp and safety clamps from the periscope.

20. Bolt a spreader bar onto the outer tube of the periscope, between the two carriages.

21. Roll the periscope, on its two carriages, to the in-board transfer opening of the upper deck.

22. Put the hook of the chain fall of the overhead track in the hook opening of the horizontal lifting spreader bar. Transfer the weight of the periscope to the chain hoist, and remove the two carriages.

23. Lower the periscope to the overhead chain hoists of the main deck. Transfer the weight of the periscope to the chain hoists of the main deck, attaching a hook in the shackle at each end of the horizontal lifting spreader bar, as in figure 9-9.

24. Roll the periscope into the optical shop, and lower it onto the separated channel optical benches. Remove the spreader bar and lifting clamps.

CASUALTY ANALYSIS AND REPAIRS

Hold a casualty analysis as you would for any other optical instrument by checking for chipped or broken lenses and dirt on lenses. Always check the periscope collimation before beginning to overhaul it. This will help to determine what might be wrong with the instrument. Record all findings on the casualty analysis sheet and refer to them while overhauling the periscope. Remember, disassemble only to the extent necessary to make needed repairs. Refer to the 8B periscope technical manual for the details that are needed to overhaul this periscope.

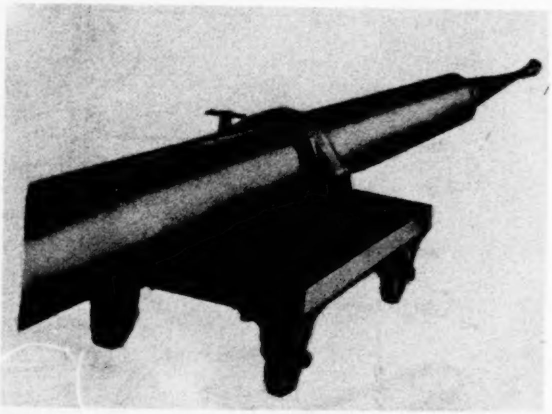


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Figure 9-8.—Upper part of periscope in clamp carriage.

INSTALLING A PERISCOPE

After the overhaul and collimation are completed, install the periscope in the submarine by following these steps:

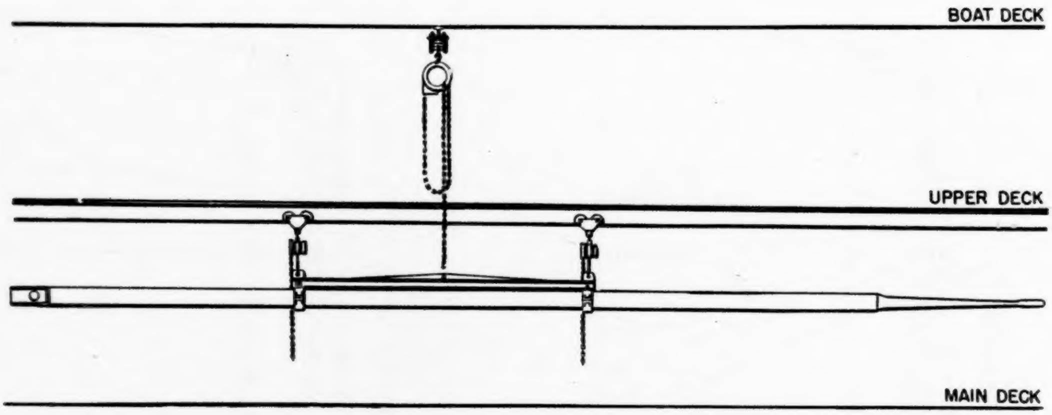
1. Remove the packing gland and the packing assembly (see figs. 9-10 and 9-11) from the hull casting of the submarine.

2. Transport the periscope from the optical shop to the submarine by reversing the procedure used to move it to the optical shop.

3. Lower the base of the periscope a short distance into the hull casting of the submarine. Apply grease freely to the outer tube of the periscope as it enters the guide bearings.

4. Attach the hinged clamp and handles to the outer tube of the periscope. Rotate the periscope back and forth while lowering it, to check for binding.

5. When the periscope has been lowered to the observing position, replace the hull packing assembly. Ordinarily, you will use Garlock chevron packing, as shown in figure 9-10. It consists of an upper metal packing ring, a ring of Garlock chevron packing, a lantern ring, two more rings of chevron



148.104

Figure 9-9.—Periscope transferred to overhead chain hoist of main deck.

packing, a lower metal packing ring, a filler ring, and the metal packing gland. In reassembly step 10 pack the cavity around the lantern ring with grease.

6. Assemble the Garlock chevron packing assembly loosely on a work bench or table, and measure the distance from the upper surface of the upper packing ring to the inner shoulder face of the packing gland. Now, in the hull casting of the submarine, measure the distance from the lower face of the lower guide bearing to the lower face of the extension ring. This second measurement should be 1/16- to 3/32-inch longer than the first, to provide the clearance shown in figure 9-10. If there is insufficient clearance, replace the filler ring with a shorter one, or cut it down on a lathe.

7. Assemble the Garlock packing assembly in the hull casting, and bring the packing gland hard against its shoulder. Now with a 0.006-inch feeler gage, check the clearance between the outer tube of the perioscope and the inner circumference of the packing gland. The clearance should be uniform all the way around.

Note: At this point we will discuss packing leakage. When leakage occurs through the Garlock packing, you will be expected to fix it. The usual cause of leakage through the chevron packing is distortion of the packing ring, which opens up a crack between the packing and the periscope. Usually the leakage can be stopped by removing the packing and replacing it, or by adding an extra packing ring. If the leakage continues, replace the chevron packing with flax packing, assembled as shown in figure 9-11. This will stop the leak, but has the disadvantage of making the periscope harder to train. Cut the flax packing rings with square ends, and measure them to fit the inner circumference of the hull casting, rather than the outer circumference of the periscope. As you bring up the packing gland, be sure to check for uniform clearance with a feeler gage. This is especially important with flax packing, since the gland is not brought all the way up against the extension ring.

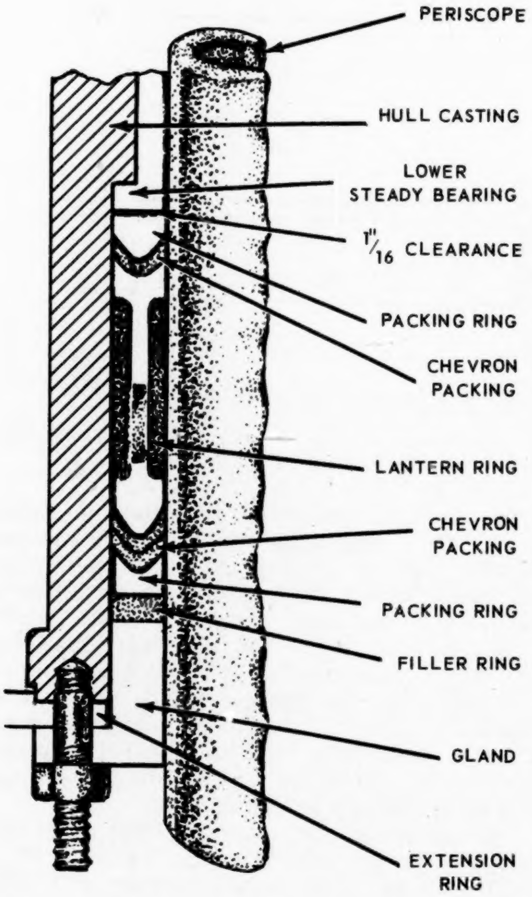
8. Assemble the azimuth circle and auxiliary circle attachment to the extension ring. Train the periscope on the forward and after bench marks of the submarine, to be sure the azimuth circle reads correctly on the lubber's line.

9. Reassemble the hoisting yoke, and fill it with mineral grease, Grade II medium.

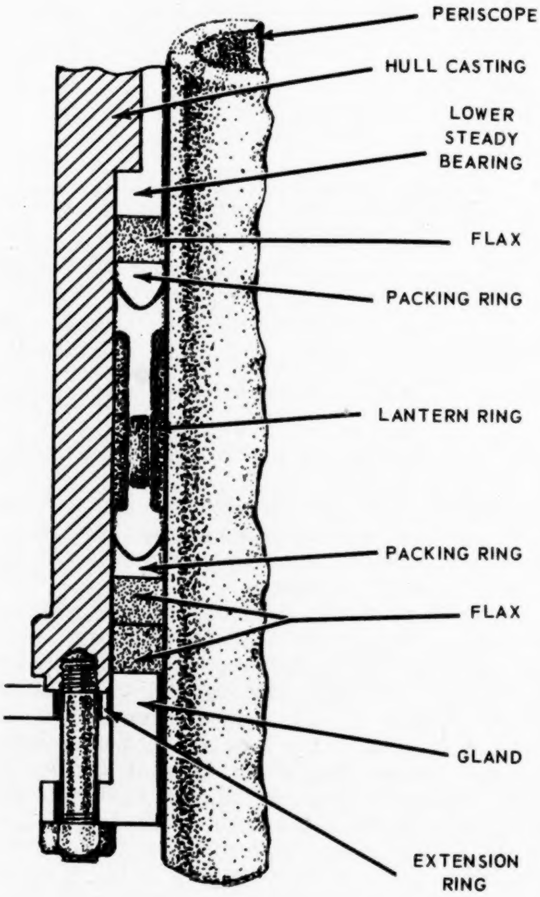
10. Now, while raising and lowering the periscope, fill the lantern ring cavity, through the external grease fitting of the hull casting, with mineral grease, Grade II medium.

11. Assemble all the external parts of the eyepiece box, following the disassembly steps in reverse.

12. Train the periscope several times through 360°, and watch the azimuth circle. If the periscope grinds against it, the circle has been improperly mounted. Remount it in the proper position. While training the periscope, listen for grinding in the guide bearings. If you hear grinding, it probably means that chips of metal have fallen into the bearings


PERISCOPE
HULL CASTING
LOWER STEADY BEARING
1"/16 CLEARANCE
PACKING RING
CHEVRON PACKING
LANTERN RING
CHEVRON PACKING
PACKING RING
FILLER RING
GLAND
EXTENSION RING

148.105
Figure 9-10.—Garlock chevron packing.


PERISCOPE
HULL CASTING
LOWER STEADY BEARING
FLAX
PACKING RING
LANTERN RING
PACKING RING
FLAX
GLAND
EXTENSION RING

148.106
Figure 9-11.—Emergency flax packing.

during assembly. To correct this, the periscope must be withdrawn, the outer tube scratches smoothed down, and the guide bearings cleaned and repacked.

13. Check the periscope training handles, the altiscope, and the power shift, to be sure they are all functioning properly. Check the stadimeter in the observing position, to be sure there is no double image at the infinity reading. Check the focusing adjustment; the range of diopter setting should be from -3 to + 1 1/2 diopters.

14. When the periscope is in satisfactory condition, report to the submarine officer and ask him to inspect it for approval.

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CHAPTER 10

SHIP-MOUNTED BINOCULAR

The ship-mounted binocular is used by the quartermaster or signalman in conjunction with visual signaling operations on many ships. The Navy uses both the Mark 3 Mod 1 and the Mark 3 Mod 2 ship-mounted binocular. Except as noted herein, the only difference in the two Mods is that the Mod 1 binocular is secured to a C-shaped bracket on the elevating carriage by a means of a dove-tailed plate, whereas the Mod 2 binocular housing is fitted with trunnions which are secured to a U-shaped yoke on the elevating carriage. The procedures for disassembly and reassembly are the same for both the Mod 1 and Mod 2.

In this chapter we will discuss the Mark 3 Mod 2 (fig. 10-1). Information is provided on the means of mounting the binocular assembly and the construction of the binocular assembly itself. Step-by-step procedures are given for the disassembly, reassembly, and charging of the binocular.

GENERAL DESCRIPTION

The ship binocular consists of four main assemblies; the binocular, carriage, pedestal, and bulkhead bracket. The pedestal and bulkhead bracket assemblies are used to either deck mount or bulkhead mount the binocular assembly. The binocular and carriage assemblies are secured together and are employed on both types of mountings. A gray canvas cover protects the binocular assembly from the weather.

CARRIAGE ASSEMBLY

An azimuth scale and an elevation scale are mounted on the carriage assembly; these permit the binocular assembly to be positioned in azimuth and elevation. The elevation scale is graduated in 1-degree increments from -10° to +60°. There are also locking devices that will hold the binocular assembly in any desired position. For vertical adjustments a handcrank on the carriage assembly permits vertical movement through a maximum range of 8 inches.

BINOCULAR ASSEMBLY

The binocular assembly contains the optics required to obtain the desired magnification and provision is made to install an illuminated reticle if required. An illuminated reticle is not provided for binoculars used aboard ship. Eyeguards are provided to exclude stray light from the observer's eyes when sighting through the eyepieces. Two focusing knobs located on each eyepiece enable the eyepieces to be individually adjusted to accommodate eyes of unequal vision. Each focusing knob is provided with a diopter scale which is graduated from -3 to +1 diopters in 1/2-diopter increments.

An interocular knob, located below the right eyepiece, is adjustable from 56 to 74 millimeters, and provides adjustment of the interpupillary distance of the eyepieces. To control the brightness of the field of view, an INCREASE DENSITY control knob is provided on the front of the binocular just below the left eyepiece. By turning this knob left or right you can control the brightness. Inlet and outlet connections are provided to evacuate and fill the binocular assembly with dry nitrogen.

BULKHEAD BRACKET ASSEMBLY

The bulkhead bracket assembly is used to mount the ship binocular on any vertical surface which allows the binocular assembly to be rotated 360° in azimuth and elevated through a range of 8 inches without any obstructions. The bulkhead bracket assembly is slotted at each side to accept swivelling eyebolts of the carriage assembly. (See fig. 10-1.)

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PEDESTAL ASSEMBLY

The pedestal assembly (fig. 10-1) may be used where deck mounting of the ship binocular is desired. The carriage assembly is inserted through the large hole of the pedestal assembly; slotted holes at the top of the pedestal accept the swivelling bolts of the carriage assembly.

DESIGN CHARACTERISTICS

The design characteristics of the Mark 3 Mod 2 binocular are:

Magnification	20 power
Clear aperture of objective	120 mm
True field of view	3°30'
Eye distance (at zero diopters)	22.5 mm
Apparent field (approx.)	70°
Exit pupil	6 mm
Interpupillary distance	56-74 mm
Maximum elevation of line of sight	60°
Maximum depression of line of sight	-10°
Overall binocular length (sunshade extended)	20.375 inches
Overall binocular width	22.5 inches
Height above bulkhead bracket or pedestal	
Extended (eyepiece LOS)	35.375 inches
Retracted (eyepiece LOS)	27.375 inches
Component weight	
Binocular assembly	51 pounds
Carriage assembly	105.5 pounds
Pedestal assembly	66 pounds
Bulkhead bracket assembly	29 pounds

PRINCIPLES OF OPERATION

The ship binocular is used to magnify distant objects whose details are indistinguishable, so that the viewer may see them with greater detail.

OPTICS

The general arrangement of the optics contained in one of the two identical barrels in the binocular assembly is illustrated in figure 10-2. The objective lenses form a normal inverted image of the object entering the binocular assembly; the image travels through either a compensator lens or a polarizing filter as required by the viewer. The two porro prisms invert the image to an erect position (as viewed through the eyepieces). The objective lenses in the ship binocular are air spaced doublets which have a spacer ring between them. The eyepiece consists of three lenses: the triplet field lens, doublet center lens, and the singlet eye lens.

VARIABLE DENSITY FILTER

Each barrel contains one adjustable and one fixed polarizing filter to control the intensity of light entering the binocular assembly. The INCREASE DENSITY control rotates the adjustable polarizing filter to obtain the desired light intensity. With the INCREASE DENSITY control set to the OUT position, the control rod contacts the filter stop, which swings the fixed polarizing filter out of position so that the compensators will be inserted in the binocular assembly line of sight. The detent locks either the fixed filters or the compensators in the line of sight.

FOCUSING MECHANISM

The eyepieces are of the internal focus type. The eye lens is mounted and sealed in the lens housing assembly; the center lens and the field lens are mounted in a lens mount which may be positioned axially for focusing. When the diopter knob is rotated through a range of +1 to -3 diopters, a cam control will adjust the lens mount to produce the proper correction for the individual observer.

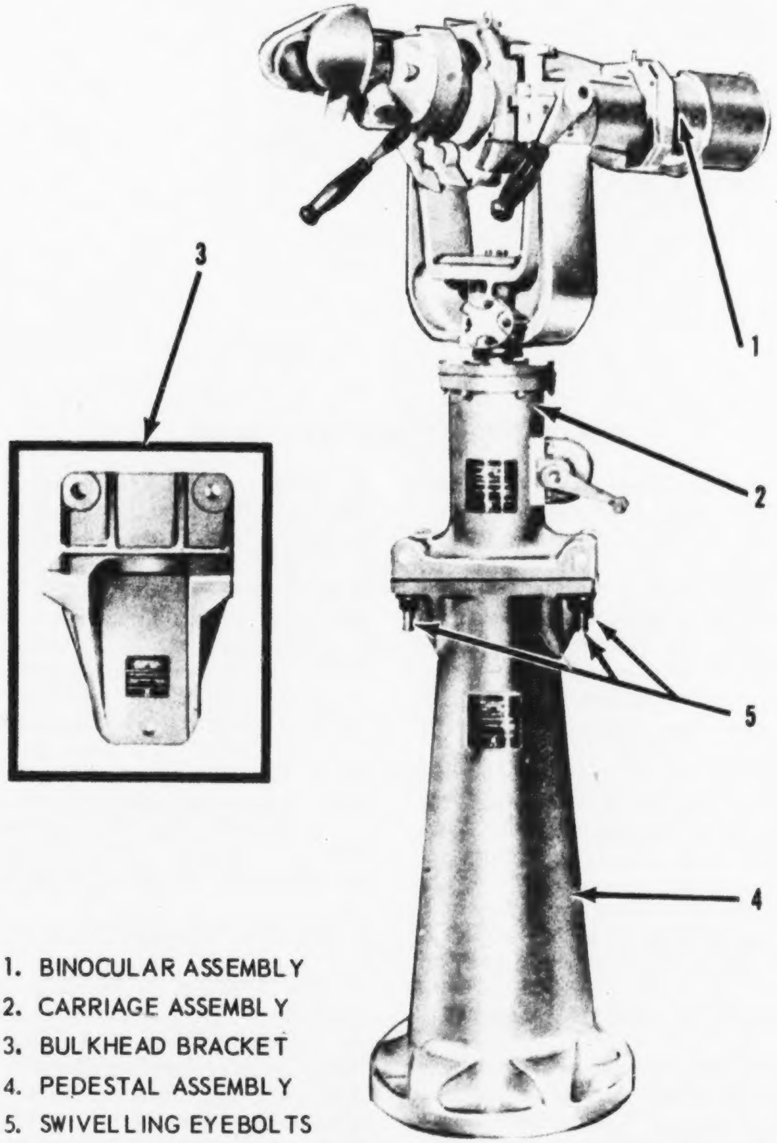
MECHANICAL OPERATION

On the top of the light filter assembly housing is the headrest; it slides onto the headrest support shaft to provide fore and aft adjustment and is locked into position by a locking nut. A hinge assembly is also provided to allow upward and downward movement of the headrest.

A handwheel is provided for locking the binocular in azimuth. Rotation of the handwheel clockwise will cause locking action by forcing the brakeshoe against the undercut portion of the elevation shaft.

MAINTENANCE AND REPAIR

This section discusses preventive maintenance and corrective maintenance for ship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1. BINOCULAR ASSEMBLY
2. CARRIAGE ASSEMBLY
3. BULKHEAD BRACKET
4. PEDESTAL ASSEMBLY
5. SWIVELLING EYEBOLTS

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Figure 10-1.—Ship binocular.

binocular. The amount of preventive maintenance that ship personnel carry out will determine how much corrective maintenance you will have to do when the ship binocular is brought to the optical shop for repair.

PREVENTIVE MAINTENANCE

Preventive maintenance of the ship binocular includes routine inspection and cleaning procedures which are performed under shipboard

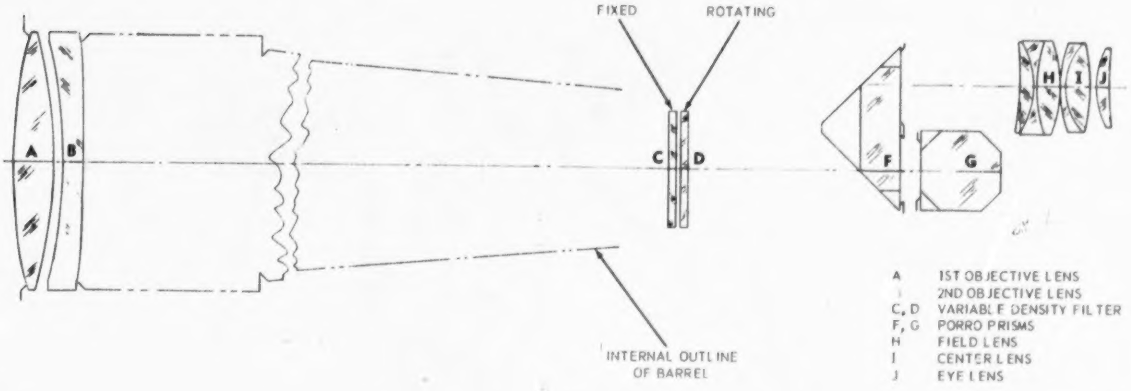

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Figure 10-2.—Arrangement of optics.

conditions. Preventive maintenance procedures should be performed without exposing the internal elements of the ship binocular to atmospheric conditions.

The ship binocular should be inspected by qualified personnel to ensure its operational capability. Perform the following inspection tests at least every six months:

1. Check that the binocular assembly is capable of being elevated from a -10° position through a +60 position without binding.
2. Ensure that the carriage assembly yoke has smooth rotation through 360° in azimuth.
3. See that the three locking devices: headrest, binocular elevation, and azimuth function smoothly and lock securely.
4. Check that all controls operate smoothly but offer enough resistance to indicate a snug fit between their respective shafts and packing rings.
5. Be sure that all external optical surfaces are clean.
6. Check that the rubber visors slide snugly along the objective mount and examine all rubber components for any signs of deterioration.
7. Check all external fastenings for tightness. After a period of excessive vibration or when shock conditions have been experienced, recheck the fastenings.

The objective and eyepiece lenses may be cleaned using lens paper or a soft, lint-free cloth which may be moistened with alcohol to remove grease. Unnecessary cleaning should be avoided. Wipe metal surfaces to remove accumulation of salt or dirt. To remove grease and oil from the rubber components, wash them with a mild soap and water solution. Note: Rubber will deteriorate if not kept dry.

Two types of fogging (external and internal) may be encountered when using the ship binocular. External fogging is a temporary condition that will disappear as the lens surface becomes warmer. To immediately remedy this condition, wipe the eyepiece and objective lenses with lens paper. Internal fogging indicates that a seal has been impaired at some point, allowing water vapor to enter the binocular. If internal fogging occurs, the binocular will have to be taken to the optical shop for repairs and recharging with dry nitrogen. (The procedure for recharging will be given later in this chapter).

CORRECTIVE MAINTENANCE

The overhaul of the ship binocular will be performed ONLY in an optical repair shop where adequate facilities and equipment for overhaul, repair, and collimation are available. The ship binocular should be overhauled only when necessary due to a malfunction of moving parts, separation of cemented lenses, a break in a seal allowing water vapor or dirt to enter the binocular assembly, or destruction or misalignment of optical parts.

If a seal has been broken, it will be necessary to disassemble the binocular to the extent required to clean and dry all optical and mechanical parts. Inspection and replacement of all packing rings, and gaskets as necessary, should be accomplished during the overhaul procedures. Immediately following the reassembly procedures, the binocular assembly should be charged with dry nitrogen.

The following checklist may be used to determine the extent of repairs necessary to return a damaged ship binocular to satisfactory operating condition:

1. Inspect the exterior of the binocular assembly for physical damage.
2. Ensure that the interocular handle operates smoothly without binding or excessive looseness.
3. Check for proper operation of the INCREASE DENSITY control.
4. View a distant object (approximately 1/2 mile) and adjust focus control of eyepiece to ensure proper definition for each eye. If proper definitions cannot be obtained, either an adjustment of the diopter controls is necessary or the optics of the binocular assembly are defective.
5. Check that the elevation, azimuth, height mechanism, and locks operate smoothly.
6. Check for internal gas pressure.

OVERHAUL

Disassemble the ship binoculars ONLY to the extent required for replacements, repairs, or adjustments. Use appropriate illustrations and general arrangement drawings while disassembling. These will help you determine the extent of disassembly. Clean the top of the bench that you will be working on and have all the tools that you will need within easy reach.

DISASSEMBLY

Before disassembling any component from the binocular assembly open the OUTLET screw (top of right barrel) to release the internal pressure if parts within the binocular seal are to be removed.

Disassemble the binocular assembly as follows (refer to fig. 10-3):

1. To disassemble the objective lens assembly remove ring (56) and the preformed packing (62) from the objective lens housing.
2. Unscrew ring (57) and remove spacer (58) from the crown objective lens, and remove crown lens (59) and wrap in lens paper and store in a safe place.
3. Remove spacer (60) and objective flint lens (61) from housing and also wrap flint lens in lens paper and store in a safe place. Note: If both objective lenses from both barrels are removed at the same time, it is advisable to keep the lenses and other components of the left and right lens mounting arrangements separated and identified so that they may be replaced properly.)
4. Next remove the optics housing from the light filter housing. First remove retaining ring (73) that secures the light filter assembly to the optics housing.
5. Next detach spring (84) from the detent arm.
6. Now remove the light filter assembly from the optics housing.
7. Remove screws to detach retaining plate from filter housing.
8. Remove washers (78 and 81), polarizing filters (79), and compensating filters (82) from housing.
9. Remove screws to detach clamp (76), and gear assembly (70 and 71) from filter housing.
10. Remove retaining rings (74), and polarizing filters (75) from filter housing.
11. Now separate the prism housing from the light filter housing. First remove screws securing sector gears (95) and sleeve bearing (96) allowing separation of the two prism housings from the light filter housing.
12. To disassemble the INCREASE DENSITY control (47) and the interocular knob assemblies (48) follow the order of index numbers in figure 10-3.
13. Refer to figure 10-3 and remove the appropriate screws to separate the prism housing from the eyepiece housing.
14. Now disassemble the prism and plate assemblies by removing the appropriate screws to separate the prism and plate assembly from the housing.
15. Remove items (37 through 39) from prism plate.
16. Loosen screws and remove retaining strap (41) and clamp pad (40).
17. Remove prisms (42) from support plate. Wrap prisms in lens paper and store in safe place.
18. Now disassemble the left and right eyepiece housing assemblies. Loosen setscrew and remove diopter knob (25).
19. Next loosen screws and remove bearing sleeve (30) and items (27 through 29, 31, and 32).

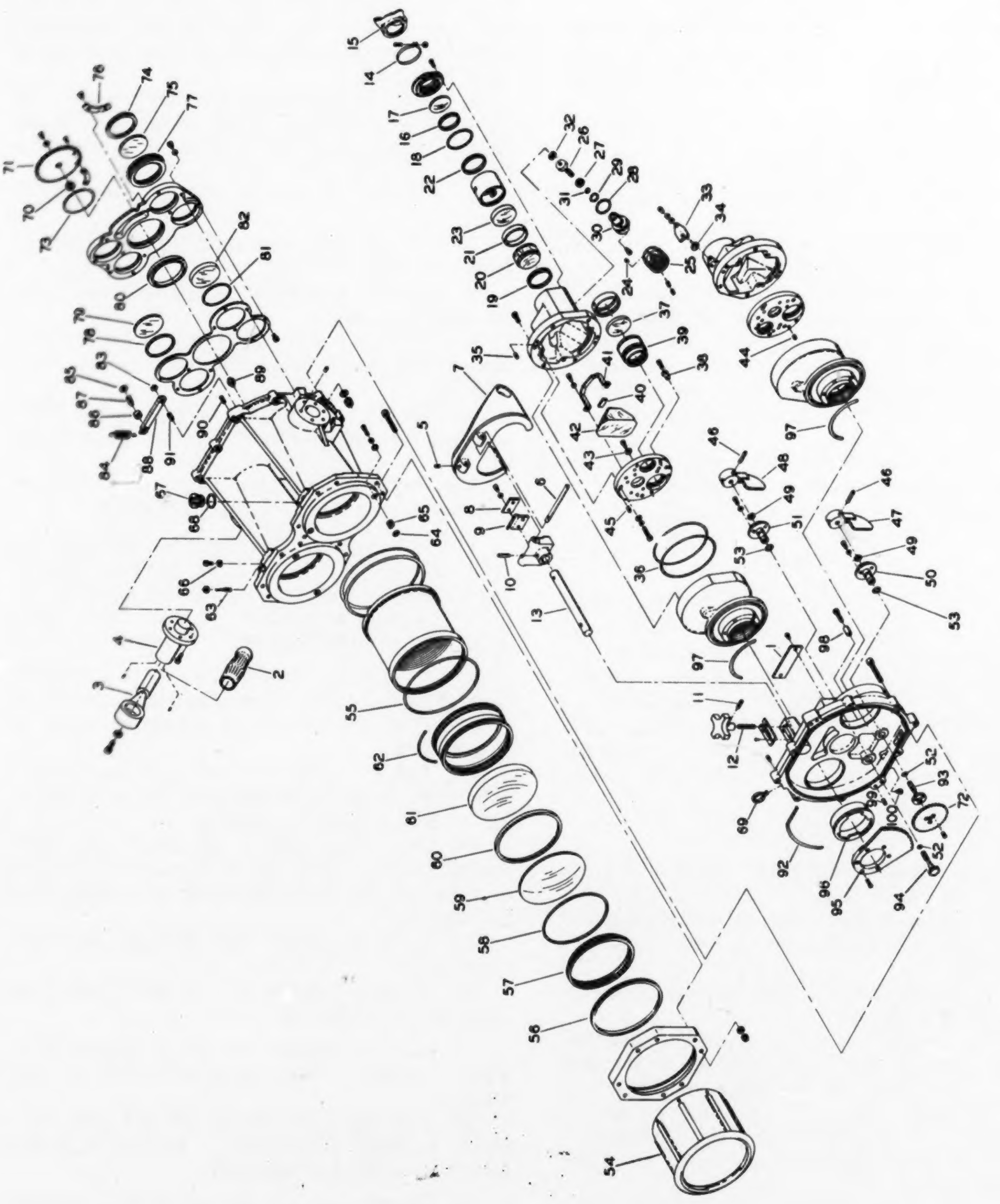
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Figure 10-3.—Binocular assembly.

20. Disassemble items (16 through 25) following the order of index numbers shown in figure 10-3.

Disassembly of the ship binocular is now completed. The next step is to repair or replace parts that are worn or damaged.

REASSEMBLY

Reassembly procedures are essentially the reverse of disassembly. Old packing should be replaced and parts which were sealed with glyptal should be carefully cleaned before resealing with fresh compound.

Match-marks noted or made at disassembly will assist in proper orientation and mating of parts. Extreme care should be exercised to prevent oil or moisture from contacting parts to be mounted inside the binocular assembly.

To reassemble the binocular assembly, do the following :

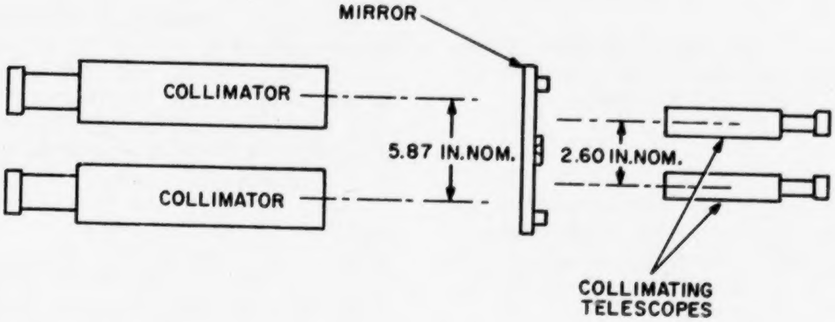
1. Apply a bead of Navy approved sealing compound, approximately 3/32 inch in diameter, to junction of outside diameter of crown objective lens (59) and housing.
2. Assemble spacer (58) and ring (57) in cell housing. Ring shall be installed to ensure metal to glass contact between items 58 and 59.
3. Apply a thin film of Navy approved high vacuum grease to all preformed packing.
4. Apply a thin film of adhesive to the housing shoulder and eyepiece lens (17).
5. Press fit filter housing shaft (89), grooved pin (90), and shouldered pin (91) into optics housing assembly.
6. Stake shoulder pin (87) to detent arm (88).
7. Press fit bearing sleeve (70) into spur gear (71).
8. Press two straight pins (44 and 45) into right-hand support plate.
9. Apply approved cement to items 40 and 41.
10. Press fit two straight headless pins (99) into binocular housing to a height of 3/16 inch.
11. Press knob stop cushion (100) into binocular housing.
12. Align hole of interocular knob (48) with hole of gear shaft (94) and insert a dummy pin. Check that end play of ear shaft is between 0.002 and 0.005 inch. If it is not, shim with flat washer (49) to obtain desired end play. Remove dummy pin and press in groove pin (46).
13. Align hole of filter knob (47) with hole of adjustment shaft (93) and insert a dummy pin. Check that adjustment shaft end play is between 0.002 and 0.005 inch. If it is not, shim with flat washer (49) to obtain required end play.
14. When assembling focusing mechanism insert assembly consisting of bearing sleeve (30), diopter shaft, and cam control (32) into diopter shaft bore of housing (with eyepiece lens assembly, 19 through 22, secured in the housing). With the flange of the bearing sleeve (30) held securely against the eyepiece lens housing, measure end play of shaft (between shaft assembly, cam control, and eyepiece lens housing, 18 through 22). End play should be between 0.001 and 0.005 inch. Disassemble and shim between bearing sleeve and diopter shaft with flat washer (27) to obtain desired end play.
15. To set diopter knob to correct mounting position with respect to its diopter scale and the reference mark on the eyepiece casting, it will be necessary to establish the zero diopter position for each eyepiece.

Insert a test reticle in place of item 37 into housing (39). The test reticle should have markings on the side closest to the objective end of the binocular. Assemble the prism plate assembly to the eyepiece housing. Set an auxiliary telescope which has been focused to suit the viewing eye of the observer against the binocular eyepiece. Rotate the diopter shaft until the image on the test reticle is in sharp focus. Position the diopter knob (25) on the diopter shaft so that the zero marking on the knob coincides with the reference mark on the casting. Secure the knob with the setscrews. Remove the test reticle and insert the optical window (3[illegible]).

16. With the eyepiece assembly correctly set and using an auxiliary telescope adjusted to the viewer's eye, the objective cell assembly can be brought into focus. Screw the objective cell in or out to bring a distant object in focus (a collimator with an infinity target may be used). Secure the objective cell with ring (56).

COLLIMATION

Two collimating telescopes are aligned on a surface plate with their axis parallel, as in figure 10-4. Two reticle collimating telescopes are aligned opposite the collimator to establish a true reference line of sight. The reticle image of each collimator is superimposed upon that of its opposite collimating telescope. The binocular is inserted and secured (with each eyepiece focused at infinity) as shown in figure 10-5.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COLLIMATOR
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COLLIMATING
TELESCOPES

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Figure 10-4.—Collimation adjustments.

Each collimator employs a reticle with a rectangle. This graphically indicates the tolerance limits within which the optical and mechanical axis of the line of sight must fall. The image of the collimator is viewed through the collimating telescopes. If the vertical and horizontal crosshairs of the reticle image intersect within the limits circumscribed by the rectangle of the collimating telescope, the binocular is aligned both optically and mechanically.

If the intersection of the reticle image falls beyond the limits of the rectangle, the binocular is out of adjustment.

To bring the binocular into collimation, two eccentric buttons (65, fig. 10-3) are provided in each objective of the optics housing and must be turned in conjunction with each other to enable horizontal and vertical adjustment of the objective barrels. When adjusting the objective barrels, loosen the square flanged ring securing the objective lens assembly.

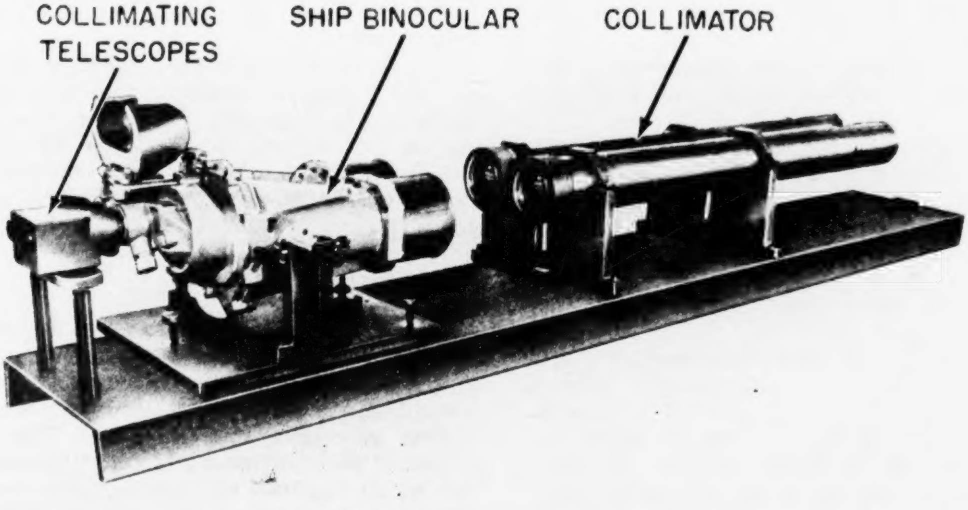
COLLIMATING
TELESCOPES
SHIP BINOCULAR
COLLIMATOR

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Figure 10-5.—Collimation setup.

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Retighten the flanged ring after collimation is completed.

NOTE: On the Mod 1 binocular, a double-eccentric ring and lens mount must be rotated with respect to each other to bring the reticled image to its optimum position within the rectangle. Turning the eccentric ring moves the objective lens mount perpendicular to the optical axis of the binocular. Turning the objective mount turns the lens on its mechanical axis and, therefore, rotates the optical center of the lens.

SEALING, DRYING, AND CHARGING

The ship binocular shall be dried and recharged with dry nitrogen whenever internal fogging occurs or a seal has been broken. Proceed with the following steps:

1. Remove OUTLET screw and washer from right barrel of the binocular.
2. Back off large INLET screw of gas inlet valve (67, fig. 10-3) to allow the entrance of dry nitrogen into the binocular.
3. Remove the inlet plug and insert an adapter connected to the nitrogen source.
4. Introduce and circulate dry nitrogen through the binocular until all air has been discharged. Replace the OUTLET screw and washers in the right barrel of the binocular.
5. Charge the binocular to a pressure of 5 psi. NOTE: Do not put more than 5 psi in the ship binocular.
6. Tighten large INLET screw and remove adapter. Replace inlet plug in the valve assembly.
7. After a period of no less than 24 hours, check with a pressure gage to determine if there has been any significant gas leakage. Any loss in internal pressure requires a recheck of the binocular seal to determine the source of the gas leakage.
8. After correcting the cause of gas leakage, if any, recycle the binocular (steps 1-7), then bleed off the gas to obtain an internal gage pressure of 2 psi. Retighten the OUTLET screw and replace the INLET plug.

CHAPTER 11

TURRET PERISCOPE

Turret sight telescopes include all the gun sight telescopes used on naval ships. Like gun sight telescopes, they provide the observer with an accurate line of sight from gun to target. The gun sight controls the angle between the axis of the gun bore and the line of sight through the telescope.

In the turret periscope, unlike some of the gun sight telescopes, the eyepiece axis is the same as, or parallel to, the line of sight to the target. We can divide telescopes into two classes: those in which the main optical system is direct, and those in which it is indirect. In the direct type, all the lenses are in a straight line: the optical axis of the telescope.

The optical system of the indirect type is basically the same except that the axis of the eyepiece is at right angles to that of the rest of the system. In front of the eyepiece is a right angle prism, to deflect the line of sight. In front of the objective is either another right angle prism or a mirror, to deviate the line of sight again.

Instruments with the indirect type of optical system are often mounted with the axis of the main tube in a vertical position. For that reason, they are usually called periscopes, rather than telescopes.

GENERAL DESCRIPTION

An example of the turret periscope we have chosen is the Mark 20 Mod 6. Figure 11-1 shows two views of it.

Figure 11-2 is a diagram of the optical system. In front of the objective is a prism. The objective, or tilting prism, is a right angle prism with the hypotenuse surface silvered, then protected with copper and a backing paint. It is fitted into a prism mount which in turn is secured in ball bearings so that the prism may be rotated through an arc of 15° in elevation, thereby permitting the line of sight to be rotated through an arc of 30° in elevation, from 15° below a plane perpendicular to the axis of the periscope.

The objective lens is a cemented doublet. It is carefully fitted into a threaded cell in the upper head assembly at the top of the optical tube. The lens is held in the cell with a threaded-in retaining ring and lock ring. By means of a lock ring the objective cell is secured in the upper head assembly in the position where parallax between a distant object and the crossline is eliminated. The crossline lens is convexo-plano (the convex surface faces the objective). The etchings are on the plane surface, and the lens is located in the second focal plane of the objective. The front and rear erector doublets are alike and each is held in a threaded cell in the upper and lower section of the optical tube and secured in position. The eyepiece prism is a right angle prism with the hypotenuse surface silvered, coppered, and painted with a backing paint. It is fitted into a stationary prism mount which is bolted and "doweled" in position in the lower head casting below the optical tube.

The sealing plate seals off the main casting, so that you can overhaul the eyepiece and color filter assembly without disturbing the other parts. The color filter assembly is of the rotating type. There are four disks: red, yellow, clear, and polaroid. The eyepiece contains a field lens doublet and an eye lens doublet, mounted in an eyepiece tube.

Figure 11-3 is a schematic diagram of the Mark 20 Mod 6 periscope. The main body tube is of cold-drawn seamless steel tubing, 1/4 inch thick. Its inside surface is nickel plated. The outside has an undercoat of corrosion resisting paint, and a finishing coat of paint. The main body tube is threaded at each end, for attaching the two end castings. The mounting sleeve is shrunk onto the main tube; it is

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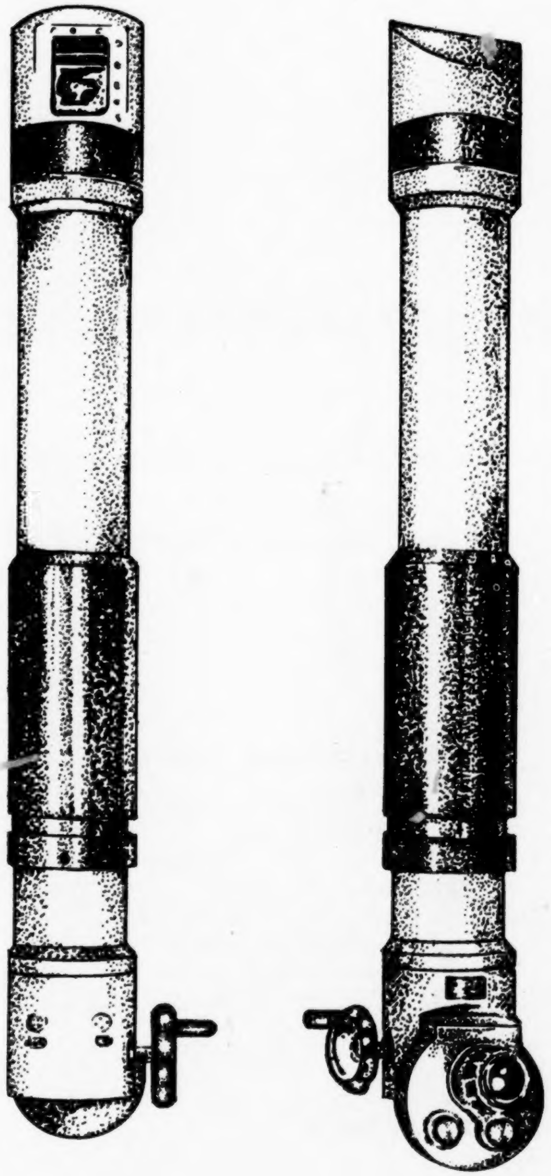
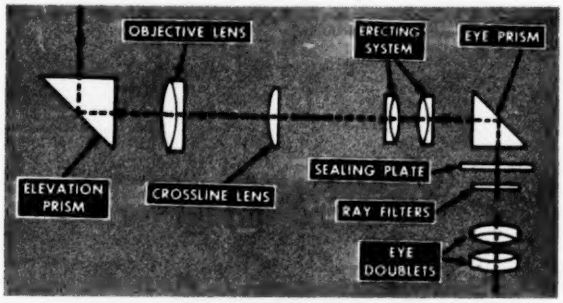


134.101
Figure 11-1.—Periscope Mark 20.

carefully machined and polished to provide a mounting surface parallel to the optical axis of the periscope.



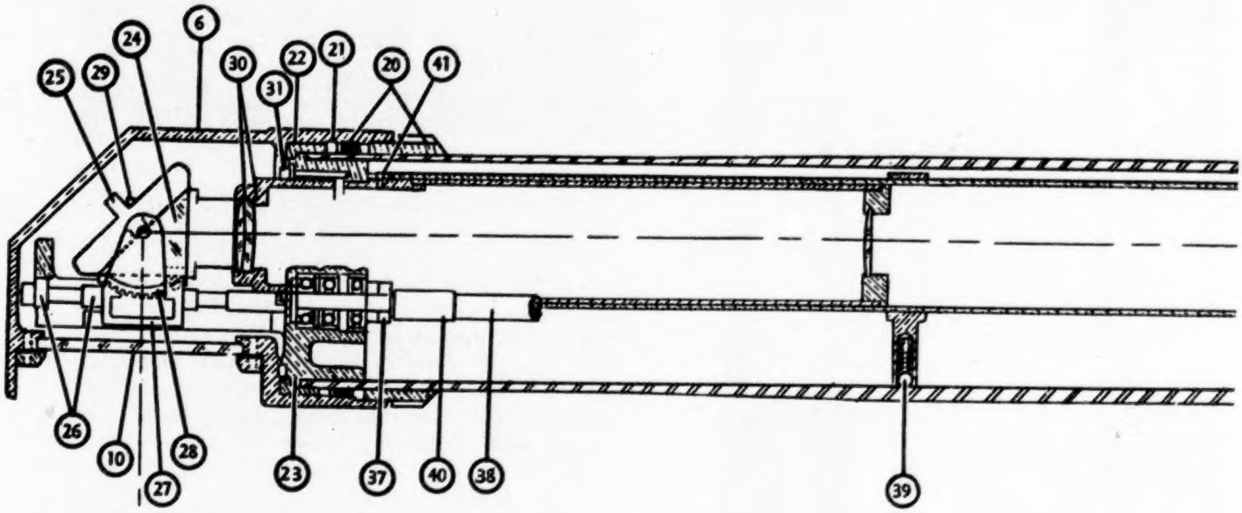
148.112
Figure 11-2.—Periscope Mark 20 optical system.

The optical tube assembly is made up of three sections. The upper section contains an inner tube which holds the crossline lens cell. The middle section holds the front erector cell. The lower section contains the rear erector cell. The optical tube is secured at the upper main casting, but its lower end is a sliding fit over a tube that is integral with the bottom casting. That arrangement lets the outer tube expand and contract, when the temperature changes, without deforming the optical tube. The optical tube is provided with a spacer frame, in which a ball bearing is held against the main tube by spring tension. This frame and its bearing keeps the optical tube on its axis, but permits relative motion between the two tubes when the temperature changes.

The handwheel, which controls the angle of the objective prism, is located on the bottom casting, to the left of the eyepiece. Its movement is limited by stops to a rotation of about 300° which is equivalent to a 30° change in the line of sight.

Situated on the right side of the filter housing is a knurled knob which can be rotated to bring the desired ray filter or clear glass into position. An arrow on the top of the knob and four engraved designations on the plate around the knob indicate which filter is in position. For each of these four positions there is a detent to hold the filter mount firmly in place.

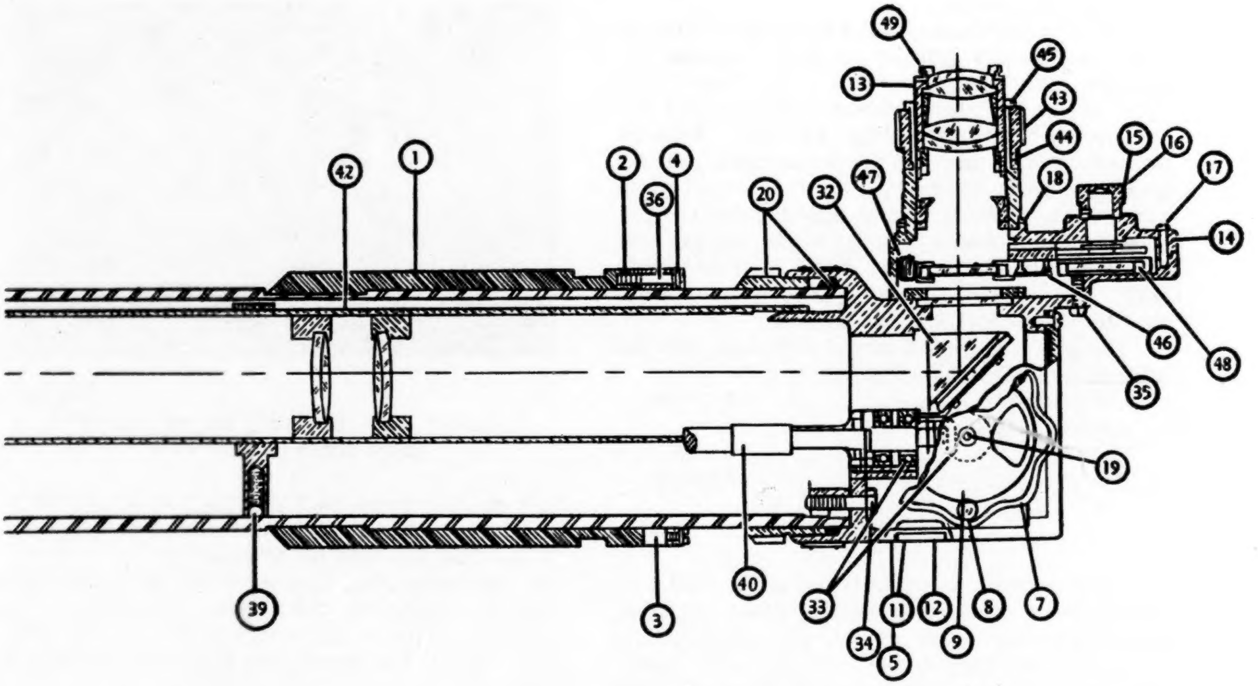
The knurled knob on the left side of the ray filter housing is designated "density." The rotation of this knob turns the polarizing plate nearer the eye, while the lower plate remains fixed, and so varies the light transmission of the combination from the maximum to the minimum. When the planes of polarization of these two plates are parallel, that is, when the transmission is at the maximum, they are oriented to reduce to a minimum the intensity of the light



1. Mounting Sleeve
2. Azimuth Ring
3. Azimuth Hole in Azimuth Ring
4. Azimuth Ring Covers
5. Lower Head
6. Upper Head Cover
7. Handwheel
8. Handwheel Crank
9. Handwheel Stop
10. Upper Window
11. Gas Outlet
12. Gas Inlet
13. Eyepiece
14. Filter Housing
15. Filter Control Knob
16. Density Knob
17. Screws to Remove Filter Housing Cover
18. Setscrew to Remove Eyepiece from Cover
19. Screw to Remove Handwheel
20. Packing Rings, Upper and Lower
    Sealing Clamp Ring
    Packing Ring
    Two Rubber Gaskets
21. Cover Clamp Ring
22. Upper Head and Optical Tube Clamp Ring (Left-Hand Thread)
23. Upper Head Casting
24. Objective Prism
25. Objective Prism Mount

148.113

Figure 11-3.—Schematic drawing, periscope Mark 20 Mod 6.



26. Sextuple Screw and Upper Bearing
27. Sextuple Screw Nut
28. Antibacklash Gear Sector
29. Prism Bearing Caps
30. Objective and Objective Cell
31. Objective Cell Lock Ring
32. Lower Prism Mount and Holding Screws
33. Bevel Gears and Bearing
34. Lower Head Bolts to Tube (3 Bolts)
35. Filter Housing Bolts (2 Bolts)
36. Azimuth Ring Clamp Bolts
37. Sextuple Screw Bearing and Lock Nuts
38. Drive Shaft
39. Two Spiders and Spring-Loaded Antishake Ball Bearings
40. Upper and Lower Shaft Couplings
41. Upper Tube Lock Screw
42. Lower Tube Lock Screw
43. Focusing Ring
44. Diopter Scale
45. Focusing Retaining Rings
46. Filter Turret Retaining Plate and Screw
47. Filter Index Roller
48. Filter Retaining Rings and Lock Screws
49. Eyeguard Ring

148.113

Figure 11-3.—Schematic drawing, periscope Mark 20 Mod 6—Continued.

reflected from a horizontal specular surface at the polarizing angle.

The gas inlet and outlet valves located on the base casting opposite the ray filter housing are marked with plates reading "gas inlet" and "gas outlet." These valves are provided for the purpose of circulating dry gas, such as nitrogen or air, through the periscope to prevent moisture from condensing on the lenses or to remove any moisture that might collect. The inlet valve connects directly to the optical tube and conducts the dry gas into it. Provision is made to circulate the dry gas from the optical tube to all parts of the instrument.

The Mark 20 Mod 6 turret periscope has the following optical characteristics:

Magnification	8 power
Angular Field	5°
Exit pupil	5 mm
Eye distance	33 mm

OVERHAUL

Disassemble the turret periscope ONLY to the extent required for replacements, repairs, or adjustments. Use appropriate illustrations and general arrangement drawings while disassembling. These will help you determine the extent of disassembly. Clean the top of the bench that you will be working on and have all the tools that you will need within easy reach.

DISASSEMBLY

The first step in disassembling the turret periscope is to release the gas pressure from the main tube. Refer back to figure 11-3 when necessary, and follow these steps:

1. Remove the rubber eyeguard.
2. Remove nine screws from the edge of the eyepiece and color filter assembly (fig. 11-4), and lift off the eyepiece and color filter mount.
3. Remove two bolts to free the lower half of the color filter assembly from the periscope body (fig. 11-5).
4. At the eyepiece end of the periscope, remove the screws that secure the end plate. Remove the end plate. (You may have to tap it gently with a rawhide mallet, to break the waterproof seal.)
5. With a special spanner wrench (fig. 11-6), loosen the packing clamp ring at the objective end of the periscope. Move the ring along the body as far as the polished steel bearing; this will expose three packing rings—one of brass and two of rubber (gaskets). Remove them.
6. With the special wrench (fig. 11-7) loosen the retaining ring that secures the upper end casting. Remove the casting to expose the elevation prism. Cover this prism at once with lens tissue, and secure the tissue so it will not come off.
7. Use the special spanner wrench to loosen the packing clamp ring at the eyepiece end of the instrument. Remove the brass ring and rubber packing rings (gaskets).
8. As you look into the lower end of the periscope body, you will see the heads of three

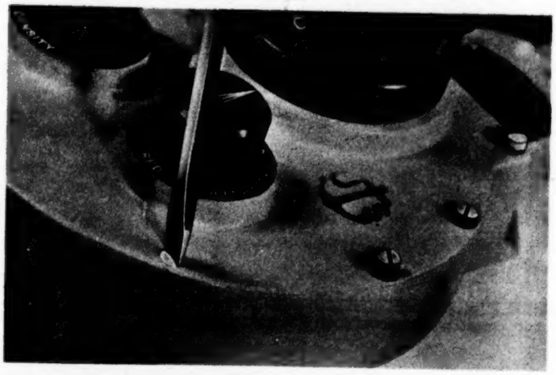

148.114

Figure 11-4.—Releasing the eyepiece and color filter assemblies.

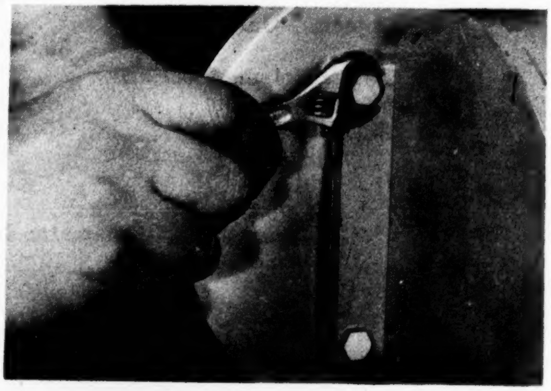

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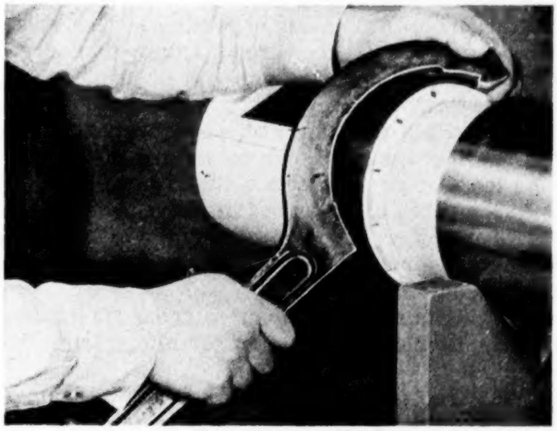
Figure 11-5.—Freeing the lower half of the color filter assembly.

bolts that secure the lower main casting. Remove the three bolts, and take the casting off the body.



148.116

Figure 11-6.—Packing clamp ring spanner wrench.

9. Inside the end of the body are two large rings, to which the lower main casting was bolted. The first ring is threaded; unscrew it from the tube. Lift out the second ring.

10. At the objective end, use a special wrench to remove the prism mount. (CAUTION: this ring has a left-hand thread.) Now withdraw the prism mount and the main optical tube. As you withdraw the tube, the ball bearing on the leg of the spacer frame will fall into a recess in the periscope body. Gently lift the tube and work the bearing over the step at the end of the recess. Remove the ball bearing and tension spring from the holding bracket.

11. With a prick punch, mark both the segment and the rack of the prism elevation mechanism, so you can reassemble them in the same relative position (fig. 11-8).

12. Remove the screws from the objective prism.

13. By turning the elevation shaft, bring the prism to a position of maximum deflection. With a rolling motion, remove the mirror and its shaft and bearings from the assembly.

14. The elevation shaft is supported on the optical tube bracket by a split bearing. Remove the upper half of this bearing. Slip the shaft and its coupling collar off the elevation worm shaft.

15. Remove the locking nut, figure 11-9, and holding nut from the outer end of the elevation worm shaft.

16. Remove the setscrew from the worm shaft bearing retaining ring. Remove the retaining ring with the special tool provided for it. Unscrew the worm shaft from the elevation rack guide block. See figure 11-10.

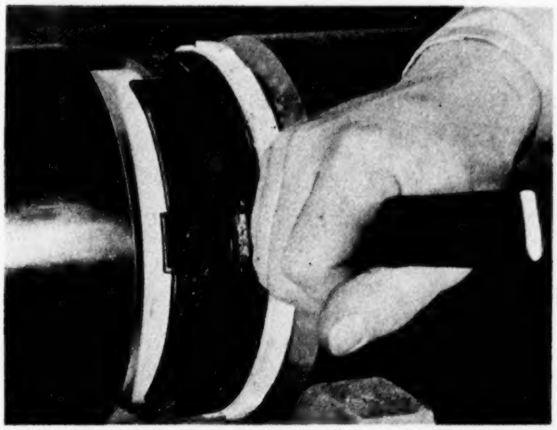


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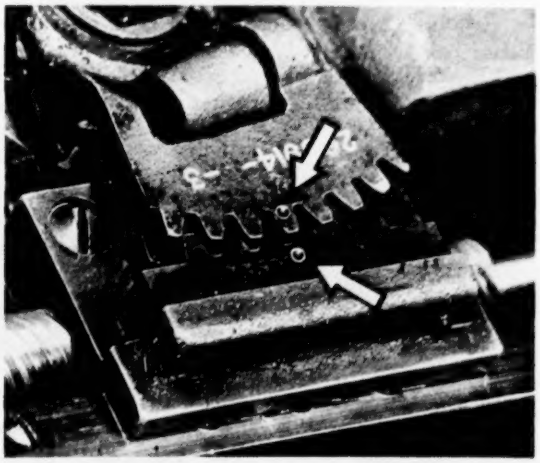
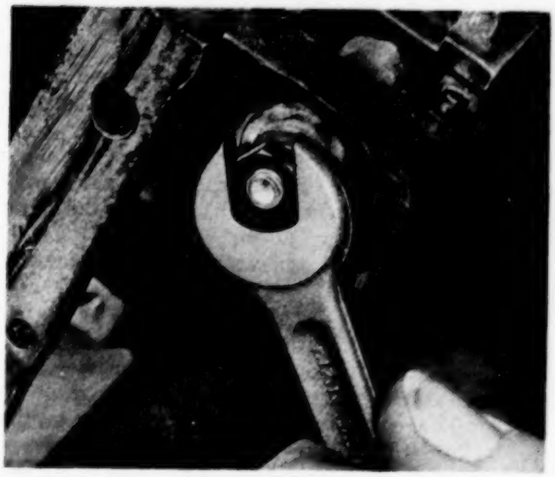
Figure 11-7.—End casting retaining ring wrench.



148.118

Figure 11-8.—Reference marks on segment and rack.



148.119
Figure 11-9.—Removing the elevation worm shaft locking nut.

17. Remove the elevation rack guide block. Under one side of the rack, you will find three spring-loaded ball bearings. They allow for adjusting the tension on the block so it will travel smoothly.

18. Remove the collar bearing from the upper end of the elevation shaft.

19. Release the objective mount lock ring. Back off the ring a few turns, and then unscrew the whole objective mount from the optical tube.

20. Remove the lock screw from the optical tube, where it joins the prism mount. Loosen the optical tube from the prism mount with a pair of strap wrenches. Remove the prism mount.

21. Find the seam where the two halves of the optical tube are joined. Scribe a line across the seam, so you can reassemble the two halves of the tube in the same position. Use strap wrenches to start the thread, and then unscrew the two halves of the tube.

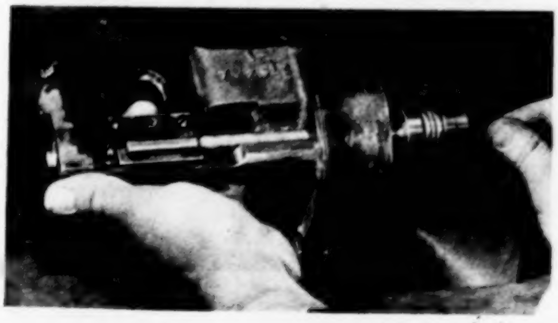
22. Remove the crossline lens mount lock screw. Hold the tube with a strap wrench, and use a fiber grip wrench to loosen the crossline lens mounts. Unscrew the mount.

23. At the other end of the tube, remove the lock screw that secures the erector mount. Unscrew the erector mount, and remove the two lens mounts from it.

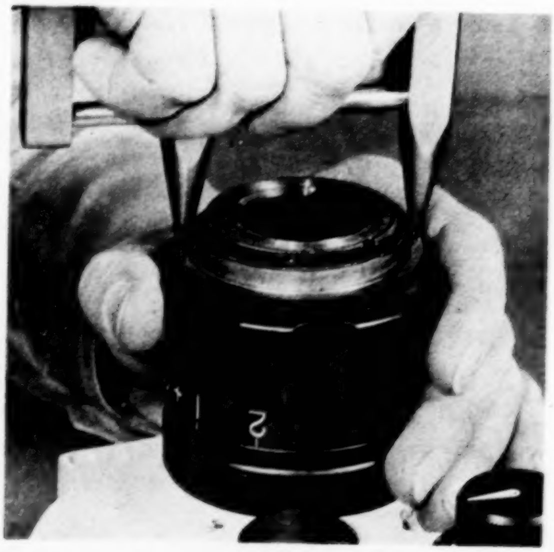
24. Remove the objective from its mount.

25. Remove the color filter mount from the eyepiece assembly.

26. Use an adjustable pin wrench to remove the lock ring from the eyepiece mount (fig. 11-11). With the same wrench, remove the retaining ring. Now turn the focusing ring off the mount. Remove the focusing key guide with a pair of tweezers. Remove the lock screws



148.120
Figure 11-10.—Removing the worm shaft.



148.121
Figure 11-11.—Removing the eyepiece mount lock ring.

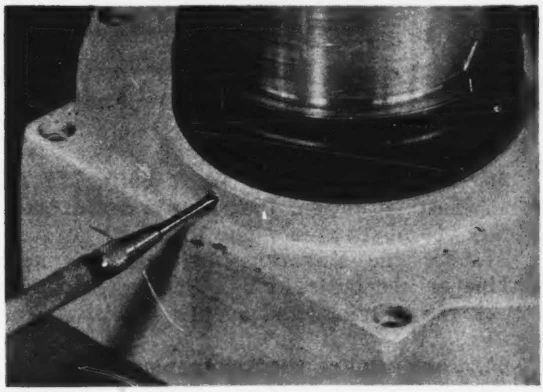
from the focusing key, and remove the key with a pair of tweezers.

27. Pull up the eye lens mount draw tube, and free it from the adapter tube.

28. Find the small lock screw at the base of the eyepiece adapter, figure 11-12, and remove it. Unscrew the adapter tube with a fiber grip wrench.

29. Disassemble the eyepiece cell.

30. Remove the four screws that secure the eye prism, and remove the prism.



148.122

Figure 11-12.—Eyepiece adapter lock screw.

31. Remove the eight screws from the sealing window retainer, shown in figure 11-13, and lift off the retainer. Remove the sealing window.

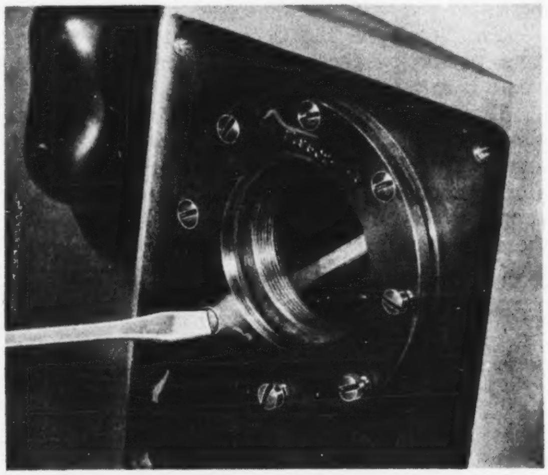
CASUALTY ANALYSIS

The casualty analysis of the turret periscope consists of inspecting the instrument after disassembly and recording the repairs needed to put the instrument back into service. By using the casualty analysis sheets, you can determine the cost of repair and the man-hours required to do the job.

REASSEMBLY AND COLLIMATION

1. Replace the eyepiece adapter, tighten it, then secure it with its lock screw.

2. Fit a string of wax on the eyepiece lens seat. Reassemble the eyepiece, and remove the excess wax.



148.123

Figure 11-13.—Sealing window retainer.

3. Lubricate the eyepiece mount and insert it in the adapter. Be sure to line up the focusing key screwholes with oblong opening. Replace the focusing key, and secure it with its two screws. Replace the focusing key guide.

4. Fit the focusing ring over the lens mount, and engage its helical slot with the focusing key guide. Screw on the focusing ring, and replace its retainer and lock ring.

5. Replace the color filter mount on the eyepiece assembly. Be sure that the filter you put under the eyepieoe opening matches the name on the indicator dial.

6. Fit the string of wax around the edge of the color filter housing. Join the two halves of the housing, and secure them with seven screws.

7. Replace the objective in its mount. Replace the front erector mount in the erector tube.

8. Replace the crossline lens mount in its position in the optical tube, and screw it up to the registration mark you made during disassembly. Secure it with its lock screw.

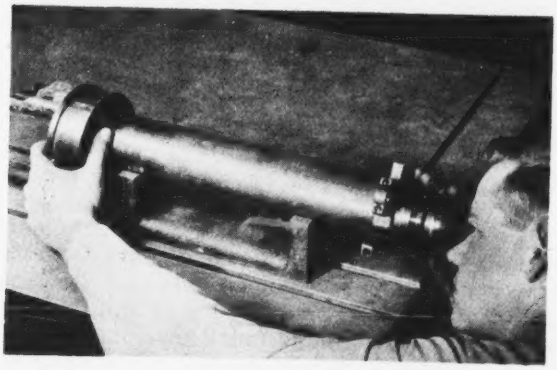
9. Screw the head prism mount to the upper section of the optical tube. Use a pair of strap wrenches to tighten it until you align the registration marks you made during disassembly. Secure the mount in this position with its lock screw.

10. Insert the objective mount in the head prism mount.

11. Insert the erector tube in the lower half of the optical tube, and secure it with its lock screw.

12. Now take the upper part of the optical tube to the periscope collimator Mark 3, and place it in a telescope holder.

13. Sight through an auxiliary eyepiece, shown in figure 11-14, and screw the objective lens mount in or out until you bring the collimator crossline into sharp focus on the periscope crossline, free from parallax. Secure the adjustment by tightening the objective mount lock ring.



148.124
Figure 11-14.—Removing parallax.

14. Join the two halves of the optical tube. Sight through an auxiliary telescope, and adjust the erector lens with a special hollow wrench (fig. 11-15) until you see the crosslines in sharp focus, free from parallax.

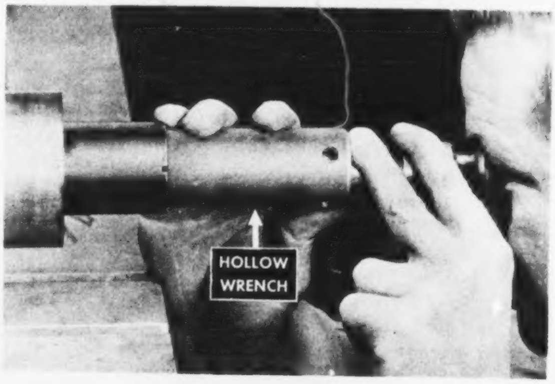
15. Now take the instrument back to your workbench. Secure the lower optical tube in position by replacing the lock screw.

16. Replace the rear erector lens mount in the erector tube. Replace the lock ring. (You will adjust both, later, at the collimator.)

17. Under the elevation rack are three spring controlled ball bearings. Replace the springs first, then the ball bearings (fig. 11-16). Replace the rack on its bearings, and thread the worm shaft into the rack.

18. Replace the lower worm shaft bearing retainer, and screw it into the prism mount with its special wrench. Secure it with its lock screw.

19. Fit the bearing over the upper end of the worm shaft, and secure it with the retaining nut and locking nut.



148.125
Figure 11-15.—Adjusting the front erector lens.

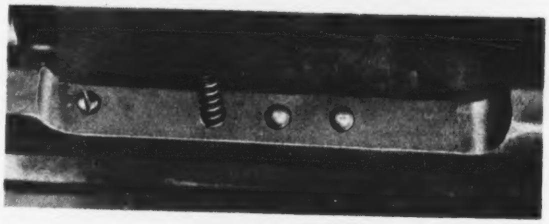
20. Fit the elevation shaft collar to the worm shaft. (Caution: the collar is keyed; there is only one position in which it will fit.)

21. Fit the elevation shaft into its split bearing on the optical tube. Replace the upper half of the bearing, and secure it with its two screws.

22. Now you are ready to replace the elevation prism. Engage the teeth of the gear segment with those of the rack so that you line up the punch marks you made during disassembly, figure 11-17.

23. Replace the two bearing brackets over the bearings of the prism shaft, and secure them with the four bearing screws. Now test the action of the prism by rotating the elevation shaft through its full travel.

24. Replace the spring and ball in the long leg of the support bracket. Insert the optical tube in the body. Remember that you have to ease the ball bearing over the recess inside the body. Fit the key on the prism mount bracket



148.126
Figure 11-16.—Elevation rack ball bearing.

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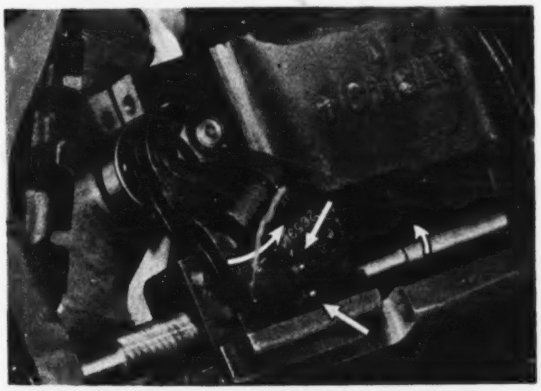

148.127

Figure 11-17.—Engaging the segment and rack.

into the notch on the end of the body. See figure 11-18.

25. Replace the head casting clamp ring, the packing rings, and the packing clamp ring on the body. (See fig. 11-19.) Screw the prism mount clamp ring over the end of the body, and tighten it with its special wrench. Turn it counterclockwise to tighten it.

26. In the eyepiece end of the body, insert the ring with the three threaded holes, but with no threads around its rim, shown in figure 11-20. Fit the cut-out around the optical tube.

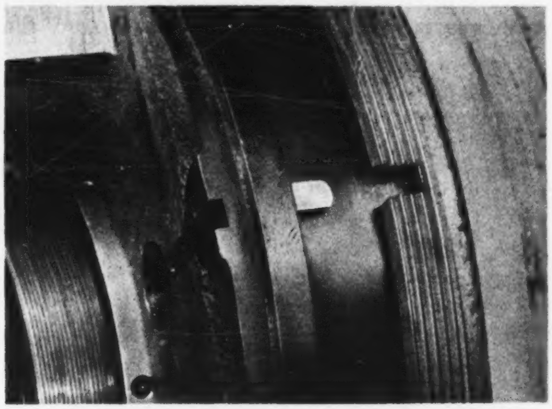

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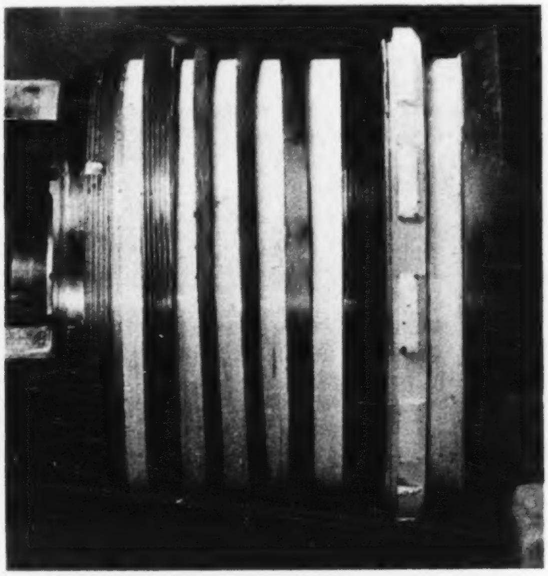
Figure 11-18.—Reassembly of the optical tube in the periscope body.



148.129

Figure 11-19.—Clamping and packing rings.

27. Screw in the threaded ring. End with the three holes and the cut-out of both rings in line.

28. In line with the key on the inside of the lower casting, make a registration mark with a lead pencil, as shown in figure 11-21. Continue the line on the outside of the casting. Use it to guide the key into the notch on the body (fig.

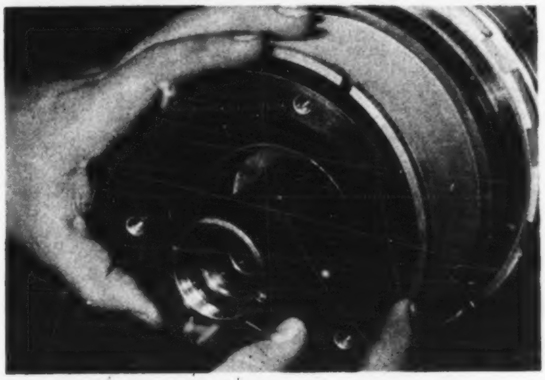


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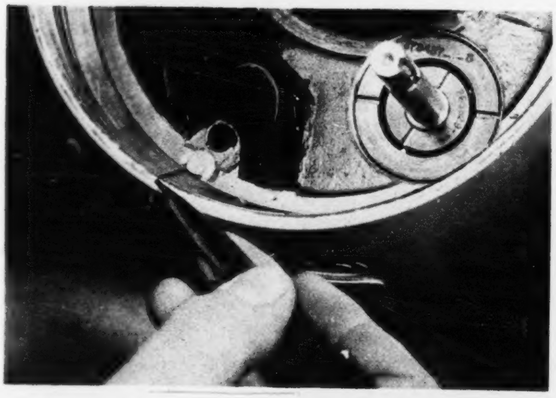
Figure 11-20.—Replacing the unthreaded ring.

11-22). Secure the casting to the body by replacing and tightening its three bolts.



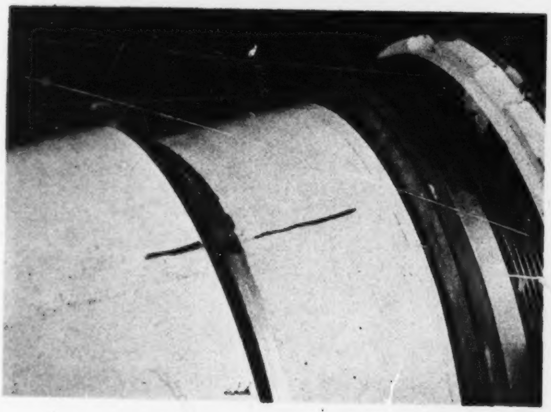
148.131

Figure 11-21.—Lower casting key registration mark.

29. Under the sealing window, place a gasket of 1/64 inch thickness. Replace the window, and put a gasket of 1/16 inch thickness over it. Replace the window retainer, and secure it.

30. Secure the eyepiece assembly to the body by two screws inserted from the top, and by two bolts inserted from the bottom.

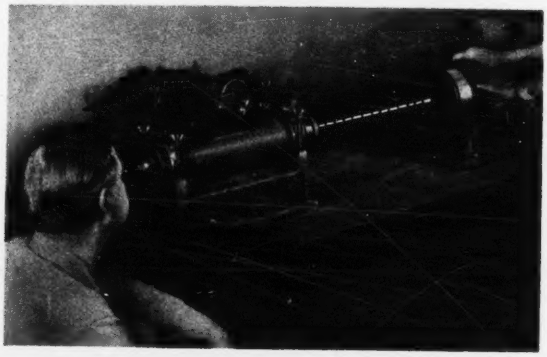
31. Bolt the fixture for holding the periscope into place on the collimator.



148.132

Figure 11-22.—Continuation of the registration mark.

32. To check the collimator alignment, put the telescope holder in the fixture, and rotate it (fig. 11-23). Both lines of sight must coincide.



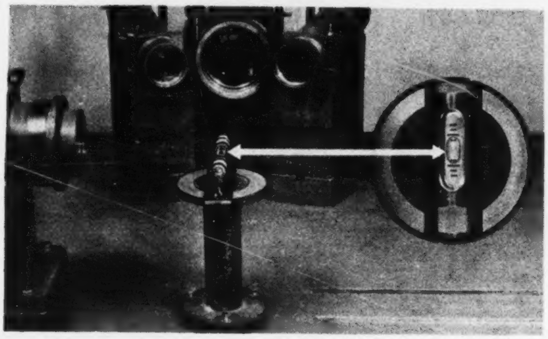
148.133

Figure 11-23.—Checking collimator alignment.

33. Carefully level the platform with an accurate spirit level, figure 11-24. You will use this platform for deviating the line of sight 90° to the horizontal collimation tube. Turn the spirit level to several different positions, to be sure the platform is accurately leveled.

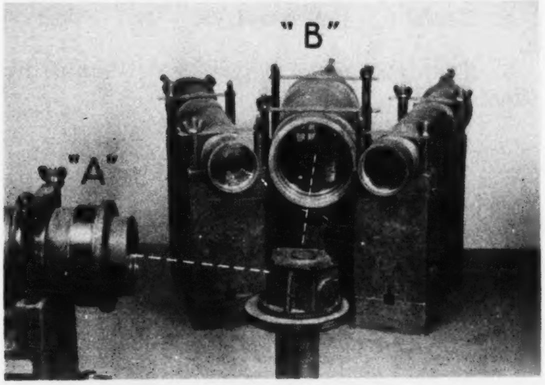
34. Put a true 90° penta prism on the platform, as shown in figure 11-25. The crosslines of "A" and "B" must superimpose.

35. Mount the periscope in its fixture, and set the focusing ring at zero diopters. Sight into the eyepiece through an auxiliary telescope. The collimator and periscope crosslines must be in sharp focus, and without parallax. If the



148.134

Figure 11-24.—Leveling the platform.



148.135

Figure 11-25.—Superimposing the crosslines.

periscope crossline is not sharp, turn the focusing ring until it is. Then look at the diopter scale. If the reading is minus, unscrew the rear erector lens and bring it back. If the scale reading is plus, move the rear erector lens forward. (You will have to remove the eyepiece prism to get at the crossline mount.) When you get the correct adjustment, secure the rear erector by tightening its retaining ring. Secure the eyepiece prism.

36. Now rotate the elevation prism handle to pick up the collimator crosslines through the 0° (horizontal) line of sight. Tilt the mirror to 15° above horizontal and then 15° below horizontal. The crosslines must superimpose in all three positions. When they do, collimation is complete. If the crosslines do not superimpose then you will have to adjust the segment gear until all three crosslines superimpose.

37. Turn the prism to maximum deflection. With the packing ring, retaining ring, and clamp ring in place, fit the head casting over the end of the body. Tighten the retaining ring with its special wrench. Secure the whole assembly by tightening the packing clamp ring with the special spanner wrench.

38. Remove the eyepiece unit. Cut a gasket to fit the end plate. Replace and secure the end plate over its gasket.

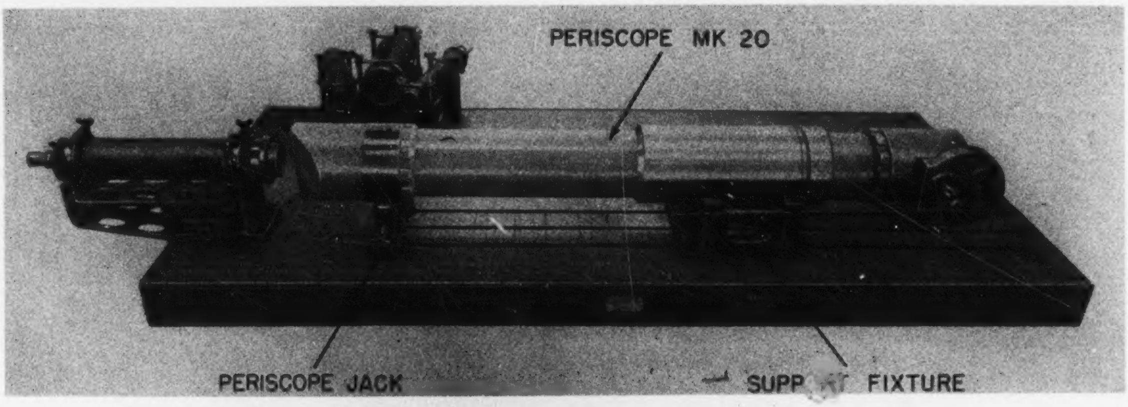
39. Now replace the periscope on the collimator and check to see if any of the adjustments have moved. See figure 11-26.

SEALING, DRYING, AND CHARGING

You have been sealing the periscope during the reassembling so there will not be any need to repeat those steps now. The next steps will be drying the periscope to remove moisture which gathers inside the instrument, and then charging the periscope.

1. Connect the nitrogen to the inlet valve of the periscope and start the gas. Unscrew the inlet valve screw and let the gas build up to 5 pounds pressure.

2. When you have 5 pounds pressure, unscrew the outlet valve screw a little and let the gas circulate slowly through the system for 5 minutes.



148.136

Figure 11-26.—Periscope Mk 20 installed on periscope collimator Mk 3.

3. When you have completed drying the system, close the outlet valve screw and charge the periscope to a pressure of 5 pounds (at this time test for leaks as you would for any other gastight instrument).

4. Now, after the test for leaks is completed, open the outlet valve and let the gas bleed down to a pressure of 2 pounds, and secure both valves.

5. Replace the eyepiece, and bolt it on.

6. Take the periscope to the collimator for a final check.

7. Replace the rubber guard.

CHAPTER 12

TILTING-PRISM TELESCOPE GUNSIGHT REPAIR

This chapter contains information on the repair and overhaul of the Mark 67 and Mark 68 telescopes. They are mounted on the twin 5-inch antiaircraft gun mount. The Mark 67 and Mark 68 are identical except that one is the "mirror image" of the other. The Mark 67 is mounted on the left of the gun mount, for the use of the pointer and the checker. The Mark 68 is mounted on the right, for the use of the trainer. See figure 12-1.

TELESCOPES MARK 68 AND MARK 67

The Mark 68 telescopes are large, mounted in fixed position, and project through ports in the gun mount shield. Since the telescope position is fixed, the observer can follow rapidly moving targets without changing his body position. Rotating prisms elevate and deflect the line of sight to follow the target. The prisms are rotated by input shafts and gears driven by the sight mechanism. The line of sight can move within these limits:

Elevation: 85°
Depression: 15°
Deflection: 20° either side

These telescopes have a fixed power of 6X, and a true field of 7°30'. The diameter of the exit pupil is 0.20 inch, and the eye distance is 1.30 inches. The optical system of the two instruments is identical, except that the Mark 67 is "left-handed" and the Mark 68 is "right-handed." Figure 12-2 is a diagram of the optics in the Mark 67.

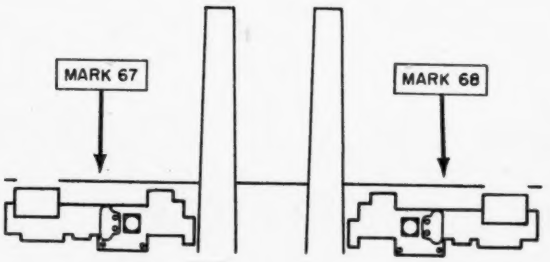
The head prism and deflection prism are both right angle prisms. But since not all the incident light strikes the entrant-light faces at a right angle, you cannot depend entirely on internal reflection. The hypotenuse reflecting faces of these prisms are silvered to ensure complete reflection. The head prism controls the elevation of the line of sight by rotating on a horizontal axis. The deflection prism rotates on an axis at right angles to that of the head prism, and controls the deflection of the line of sight.

The objective is an achromatic cemented doublet. The cross line lens is plano-convex. The plane surface carries the cross lines, and faces the objective. The cross lines are in the back focal plane of the objective. The image formed by the objective is nearly erect, since the image has been nearly inverted by the two prisms.

The erecting system consists of a pair of cemented doublets. The filters are located between the two erectors. There are three of them: yellow, red, and a pair of polaroids. Like those of the Mark 74 telescope, they are held in a common mount which you can rotate to bring the desired filter into your line of sight. The roof prism deviates the line of sight through 90°, and provides an erect image in the focal plane of the eyepiece. The reflecting surfaces of the roof prism are carried at the same angle as the reflecting surface of the deflection prism. Because of this, the roof prism elevates the line of sight about 35° above horizontal, so that the observer looks downward into the eyepice.

Figures 12-3 and 12-4 show two views of the Mark 67 telescope, and figure 12-5 shows the general arrangement of its parts. Refer to these figures as you read the following description.

The body casting is made of bronze; it is about 4 feet long, and its walls, at most points, are 0.18 inch thick. It is irregularly shaped to house the optical parts, the input mechanism, and the mounting surface. The


MARK 67
MARK 68

148.137
Figure 12-1.—Telescopes Mark 67 and Mark 68.

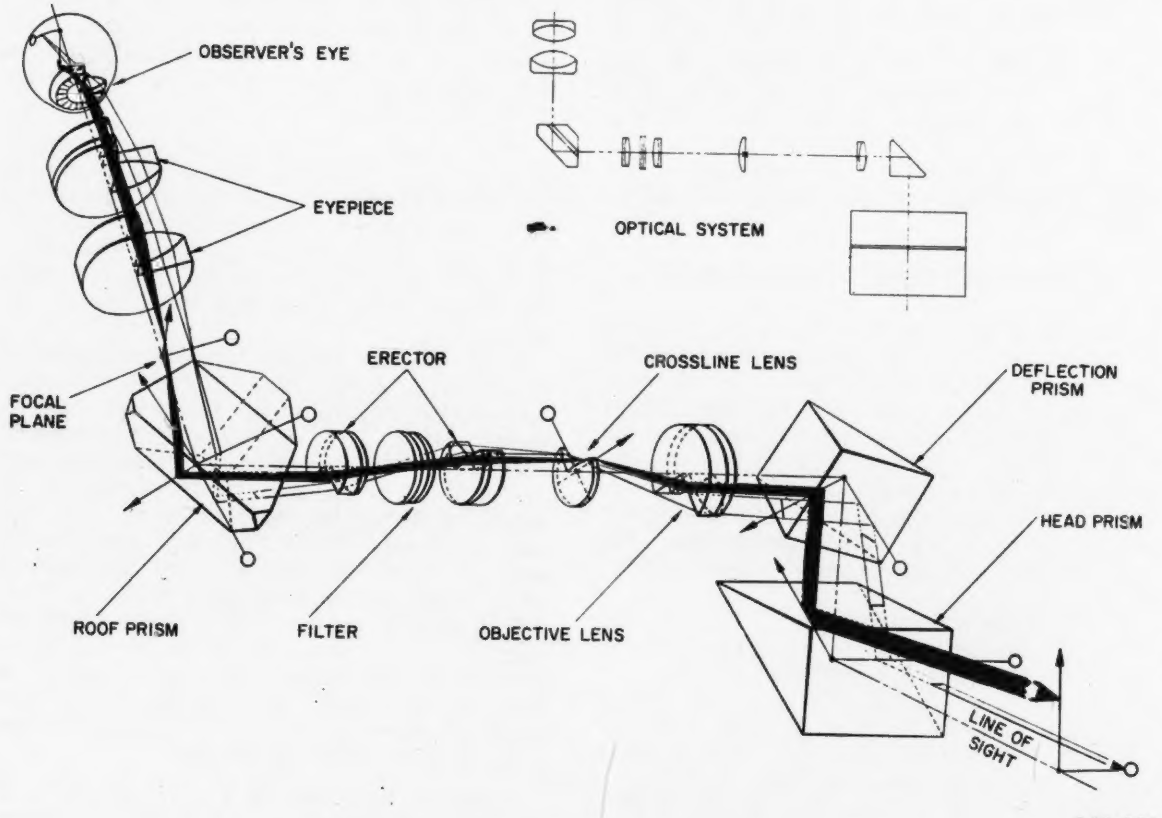

OBSERVER'S EYE
EYEPIECE
OPTICAL SYSTEM
FOCAL PLANE
ERECTOR
CROSSLINE LENS
DEFLECTION PRISM
HEAD PRISM
ROOF PRISM
FILTER
OBJECTIVE LENS
LINE OF SIGHT

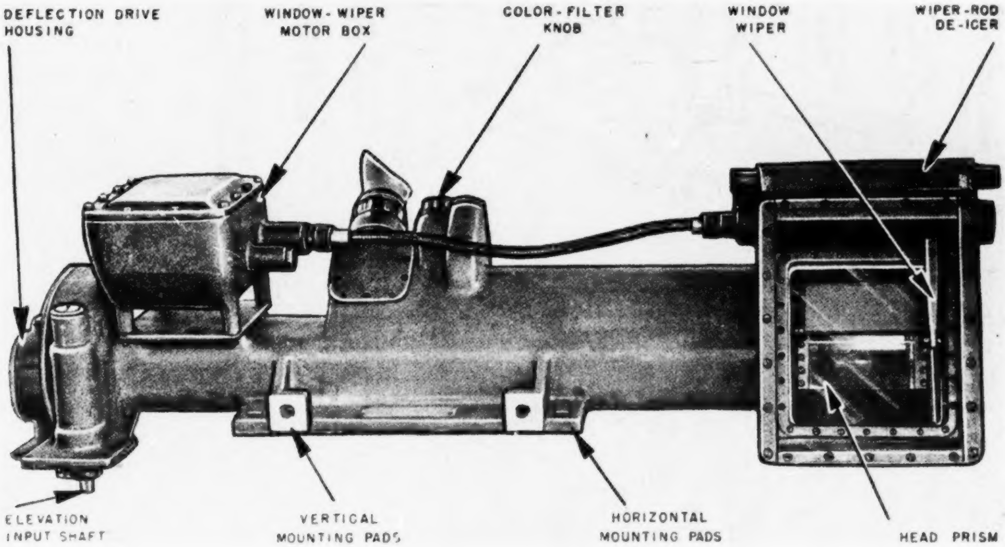
Figure 12-2.—Optical system, telescope Mark 67.

148.138

mounting pad flange is a little less than 1 foot wide, and is integral with the casting. The small square flanges at the inboard end are drilled for attaching the input brackets of the sight. The access openings into the casting are closed with caps and covers, and sealed with screws and gaskets to keep the instrument gastight. The input shafts are sealed with stuffing boxes..

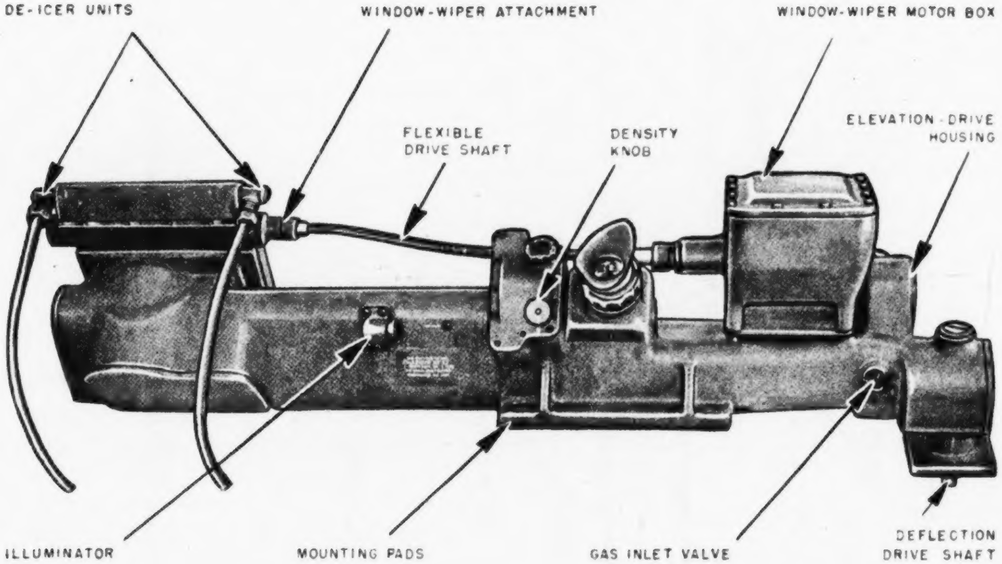
The objective window protects the optics from dirt and moisture. It fits into a recessed seat in the front outboard end of the main casting, and is held between silicon rubber gaskets by the window retainer. Fastened to the window flange of the body casting is the window-wiper frame, which supports a window-wiping attachment Mark 6. The driving shaft of the wiper is connected by a flexible shaft to a 110-volt motor mounted on the inboard end of the body casting. The de-icer is a cylindrical heater fixed to the top of the window wiper. Two cables from the junction box carry current to the electrical units of the heater. The wiper operating rod is the only part heated.

Figure 12-6 is a diagram of the elevation mechanism. A long elevation shaft, mounted in ball bearings, connects a trunnion of the


DEFLECTION DRIVE HOUSING
WINDOW-WIPER MOTOR BOX
COLOR-FILTER KNOB
WINDOW WIPER
WIPER-ROD DE-ICER
ELEVATION INPUT SHAFT
VERTICAL MOUNTING PADS
HORIZONTAL MOUNTING PADS
HEAD PRISM

148.139

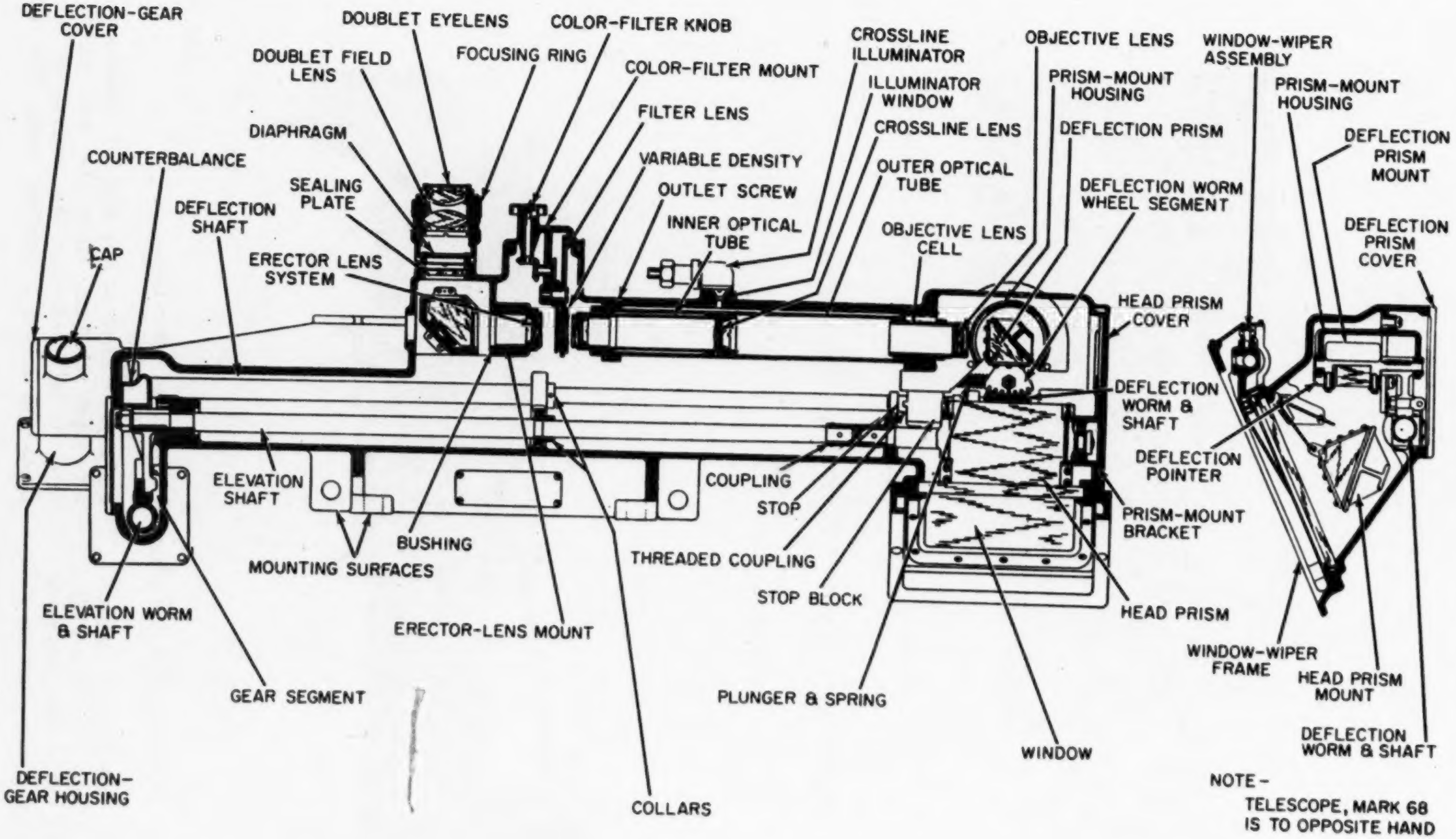
Figure 12-3.—The Mark 67 telescope, front view.


DE-ICER UNITS
WINDOW-WIPER ATTACHMENT
WINDOW-WIPER MOTOR BOX
FLEXIBLE DRIVE SHAFT
DENSITY KNOB
ELEVATION-DRIVE HOUSING
ILLUMINATOR
MOUNTING PADS
GAS INLET VALVE
DEFLECTION DRIVE SHAFT

148.140

Figure 12-4.—The Mark 67 telescope, rear view.

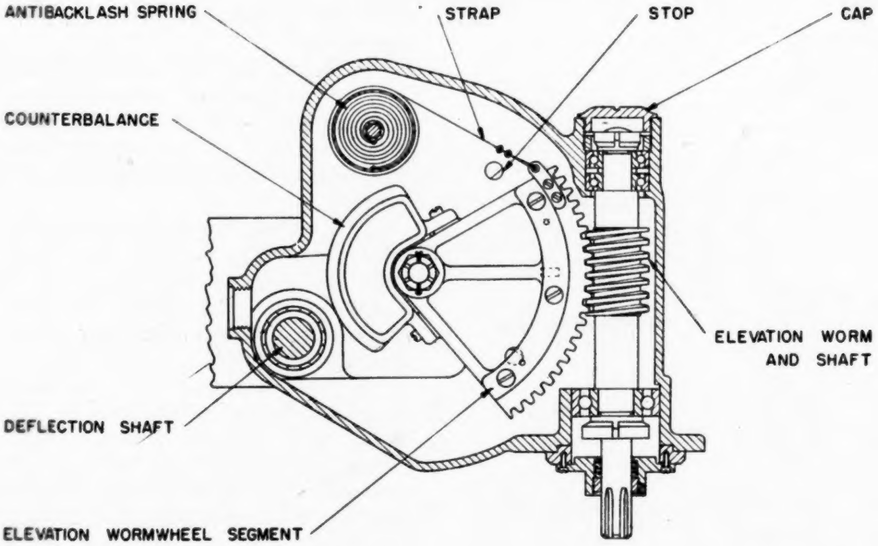
head-prism mount with the wormwheel segment. (You can see the end of the elevation shaft, with a hexagonal nut and cotter pin, near the middle of fig. 12-5.) The input shaft on the sight is splined at one end for attachment to the input shafting from the gun mount. It turns in ball bearings; the stuffing box at the input end forms a gastight seal. The worm


DEFLECTION-GEAR COVER
DOUBLET EYELENS
COLOR-FILTER KNOB
DOUBLET FIELD LENS
FOCUSING RING
COLOR-FILTER MOUNT
DIAPHRAGM
FILTER LENS
COUNTERBALANCE
SEALING PLATE
VARIABLE DENSITY
DEFLECTION SHAFT
OUTLET SCREW
CAP
ERECTOR LENS SYSTEM
INNER OPTICAL TUBE
CROSSLINE ILLUMINATOR
ILLUMINATOR WINDOW
CROSSLINE LENS
OUTER OPTICAL TUBE
OBJECTIVE LENS CELL
OBJECTIVE LENS
PRISM-MOUNT HOUSING
DEFLECTION PRISM
DEFLECTION WORM WHEEL SEGMENT
HEAD PRISM COVER
DEFLECTION WORM & SHAFT
DEFLECTION POINTER
PRISM-MOUNT BRACKET
HEAD PRISM
WINDOW-WIPER ASSEMBLY
PRISM-MOUNT HOUSING
DEFLECTION PRISM MOUNT
DEFLECTION PRISM COVER
WINDOW-WIPER FRAME
HEAD PRISM MOUNT
DEFLECTION WORM & SHAFT
ELEVATION SHAFT
COUPLING
STOP
THREADED COUPLING
STOP BLOCK
BUSHING
MOUNTING SURFACES
ELEVATION WORM & SHAFT
ERECTOR-LENS MOUNT
GEAR SEGMENT
PLUNGER & SPRING
WINDOW
DEFLECTION-GEAR HOUSING
COLLARS

NOTE-
TELESCOPE, MARK 68
IS TO OPPOSITE HAND

148.141

Figure 12-5.—The Mark 67 telescope, general arrangement.



148.142

Figure 12-6.—Elevation mechanism.

gear on the input shaft operates the sector, which in turn rotates the long elevation shaft. Notice the antibacklash device. The tension of its spring is adjustable.

Figure 12-7 shows the input end of the deflection mechanism which drives the deflection prism. The end of the shaft is splined for attachment to the input shafting from the gun mount. The shaft moves in ball bearings, and is sealed by a stuffing box. The mechanism uses a pair of bevel gears to rotate the long deflection shaft. Find the end of the shaft in figure 12-7. Now look at figure 12-8 and find the other end of the shaft, to understand how the two drawings are related.

Figure 12-8 shows the deflection prism mount. A worm mounted near the end of the long deflection shaft operates the wormwheel segment, which in turn rotates the prism on its trunnion. (In this picture, you are looking at the edge of the segment.)

The outer optical tube is supported in cylindrical bearings in the main casting. There is a lock ring to hold it in place, and a setscrew to keep it from turning. (Keep referring back to fig. 12-5, to locate the parts as they are mentioned.) The objective cell is adjustable along its axis, so you can remove parallax; there is a retaining ring to secure the adjustment. The two erectors are in separate mounts; the front erector lens mount is located in the inner optical tube, the rear one is located in a separate bushing in the main casting.

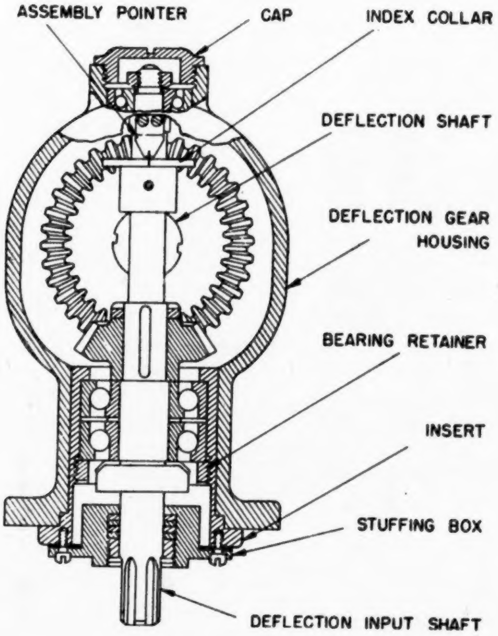
By referring to figure 12-5 again, you can see how the roof prism, the color filter assembly, and the eyepiece assembly are mounted in the housing. Notice the sealing plate between the eyepiece and the telescope body. It is there so you can overhaul the eyepiece, if necessary, without opening the main casting.

The Mark 67 Mod 1 is the same as the Mark 67, except for minor differences in curvatures and indexes of refraction of some of the lenses. We doubt if you can tell the difference when you overhaul them. But be careful—the optical parts are not interchangeable from one to the other. The same thing is true of the Mark 68 and the Mark 68 Mod 1.

OVERHAUL

Your inspection should show you exactly what is wrong with the instrument. Repair only the damaged parts. Complete disassembly is a long, complicated job. You will often find that all you need is an overhaul of the eyepiece or the color filter assembly. So do not make extra work for yourself.

The Marks 67 and 68 telescopes are rugged instruments, built to withstand the shock of gunfire. But that does not mean you can handle



148.143
Figure 12-7.—Deflection mechanism.

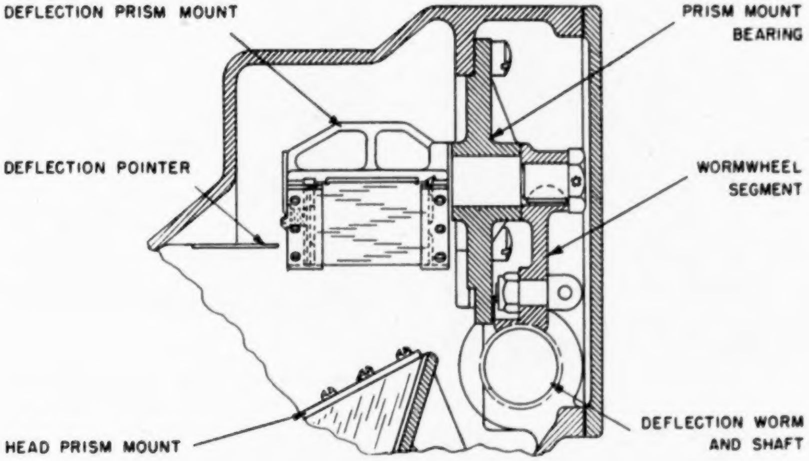
them carelessly. Gunfire is a special kind of shock—the instruments are not built to be jolted and banged around. The complete telescope weighs about 180 pounts, yet you must handle it as carefully as you would a watch. Moving it from one spot to another is a job for at least three men. Do not take chances—get help when you need it.

We will give you complete instructions for overhauling and collimating the Mark 68 telescope. Our pictures are mostly close-ups, so refer back to figures 12-3, 12-4, and 12-5 if you have trouble locating the parts.

DISASSEMBLY

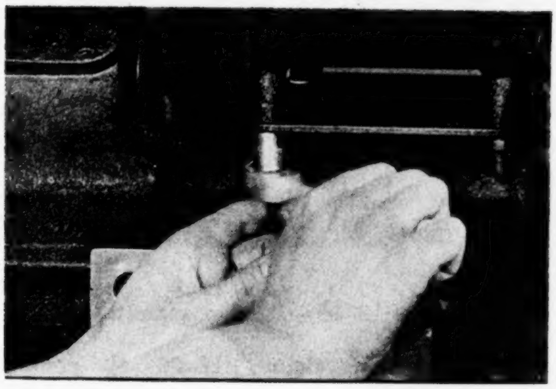
Do not forget to make an inspection before disassembly. Be sure to check for correct assembly marks; make them, if necessary. Then follow these steps:

1. Loosen and remove the screw from the air outlet. When all the gas has escaped from the telescope, replace the screw.
2. Disconnect the flexible window wiper cable from the motor drive unit.
3. Remove the four nuts from the motor drive unit plate (fig. 12-9). Remove the seven screws from the strip on each side of the elevation prism window (fig. 12-10). Lift off the strips.
4. Removing the window strips will expose the four bolts that secure the window wiper attachment. Remove these bolts and their nuts (fig. 12-11). Lift the entire window wiper attachment, and its flexible cable, off the telescope window.
5. Remove the 16 screws from the elevating gear cover (fig. 12-12), and remove the cover. We have already described the elevation gear assembly for the Mark 67. The Mark 68 is the same, except that the parts face in the opposite direction.
6. Now release the tension in the antibacklash drum. First tightly by rotating the drum with a screwdriver. This will free the adjusting pin so it can be removed (fig. 12-13). Release the tension a few notches at a time, holding the drum with the adjusting pin while you shift the screwdriver to a new notch.
7. Remove the two screws that hold the antibacklash strap on the gear segment. Remove the four screws from the antibacklash drum shaft support. Remove the support, the drum, and the strap.
8. Now remove the packing gland from the elevating input shaft. (You will need the special tool shown in fig. 12-14).
9. Now remove the cap from the input shaft with the special wrench shown in figure 12-15. Use the special wrench shown in figure 12-16 to remove the nut from the end of the elevation input shaft. Remove the locker washer.
10. Now withdraw the elevation input shaft through the packing box opening. This step takes a lot of care. First: do not scrape the threads of the worm gear over the segment teeth, and do not bang them against the sides of the gland housing. Second: support the segment with your free hand, so it will not fall against its stop when you free the input shaft.
11. Remove the small lock screw that secures the retaining ring over the input shaft thrust bearing (fig. 12-17).
12. Use the special tool shown in figure 12-18 to remove the retaining ring. Press the two thrust bearings and their separator out from the bottom using a block of wood.
13. Remove the counterbalance from the gear segment by removing the two screws shown in figure 12-19. Remove the bottom screw first, then the top one.



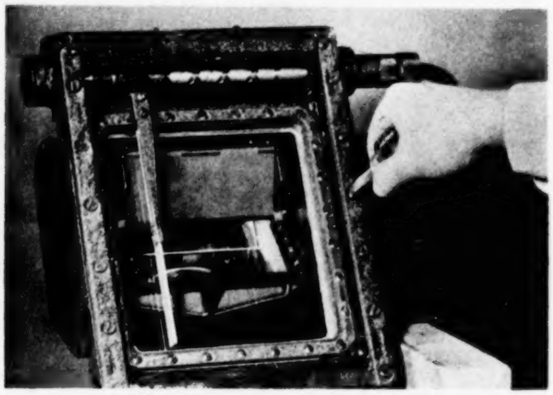
148.144

Figure 12-8.—Deflection prism mount.



148.145

Figure 12-9.—Releasing the motor unit.



148.146

Figure 12-10.—Unscrewing the window strips.

14. Pull the cotter pin from the nut on the end of the long elevating shaft. Remove the nut and lock washer. Use a special gear puller set to remove the gear segment from the shaft (fig. 12-20). Screw part A on the shaft, insert the screws marked B in the threaded holes in the gear segment, and pull the gear by turning the knob C clockwise.

15. The next step is to remove the objective window. First, remove the 26 screws from the window retainer, and lift off the retainer. Since the window itself may be waxed into place, removing it may be a two-man job. One man can move the window from side to side with orangewood sticks, while the other lifts with a suction cup (fig. 12-21).

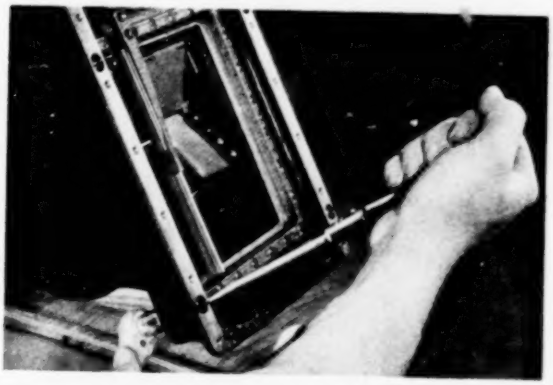
16. Remove the two screws that hold the shutter in place on the prism mount (fig. 12-22). Take off the shutter.

17. Remove four screws each from the right and left shutter guides (fig. 12-23), and lift out the guides.

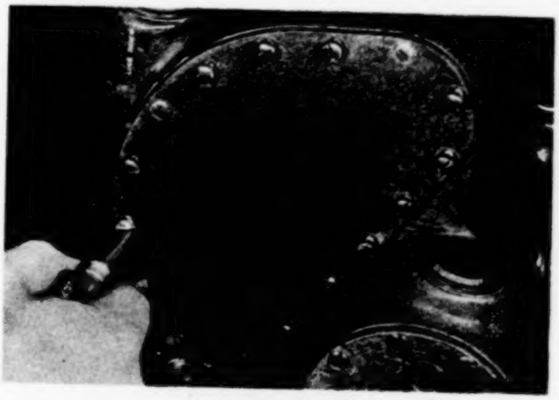
18. Loosen and remove the 15 screws that hold the head prism cover in place. Remove the cover.

19. Loosen and remove the 18 screws that secure the deflection prim cover.

162



148.147
Figure 12-11.—Releasing the window wiping attachment.

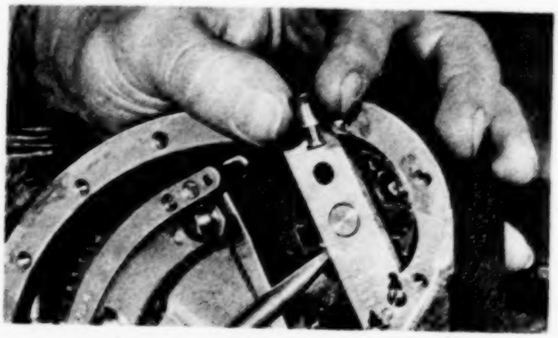


148.148
Figure 12-12.—Releasing the elevating gear cover.

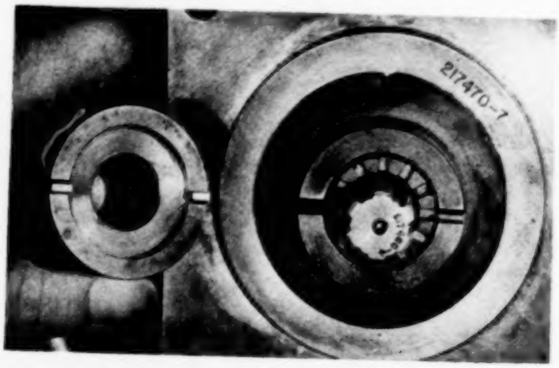
(It is directly behind the window.) Remove the cover.

20. Loosen and remove the eight screws from the head prism bearing bracket (fig. 12-24). Remove the bracket. Now carefully pull the head prism and its shaft out through the opening in the body. Be careful not to chip the edges of the prism. Pull in a straight line, supporting the prism and shaft with both hands.

21. Remove the small setscrew that locks the retaining rings on the head prism shaft thrust bearing (fig. 12-25). Use the special tool shown in figure 12-26 to remove the retaining ring.



148.149
Figure 12-13.—Releasing tension from the anti-backlash drum.



148.150
Figure 12-14.—Packing gland tool.

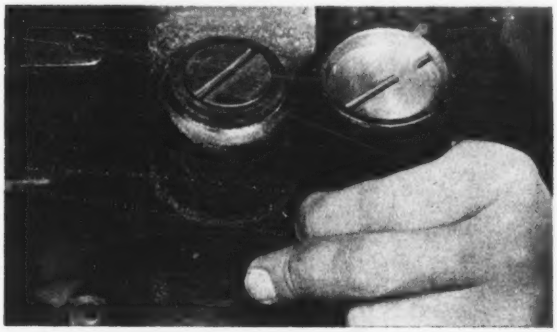
22. Remove the two thrust bearings and their separator.

23. Remove the small setscrew from the deflection prism worm shaft bearing lock ring (fig. 12-27).

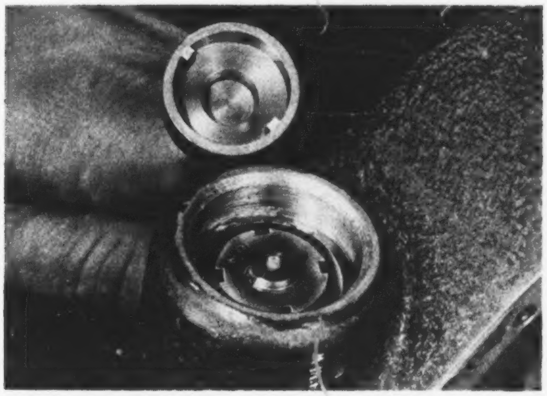
24. Remove the bearing lock ring with the special tool provided for it.

25. Remove the four screws shown in figure 12-28. There is a spring that will push out the plunger and plunger arm when you loosen the screws. Remove these parts.

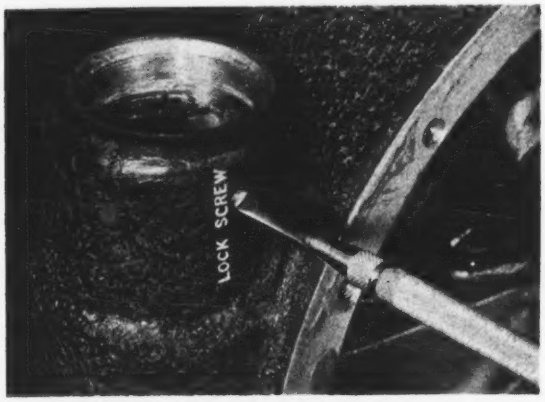
26. With the stop block centered and the deflection index and pointer aligned, scribe a line on the gear segment, to show the position of the last thread on the worm gear (fig. 12-29). You will need this mark when you reassemble.



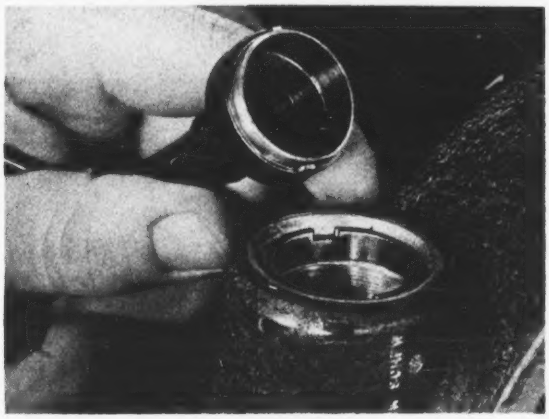
148.151
Figure 12-15.—Input shaft cap wrench.



148.152
Figure 12-16.—Elevation input shaft nut wrench.



148.153
Figure 12-17.—Removing the shaft thrust bearing retainer lock screw.



148.154
Figure 12-18.—Thrust bearing retaining ring wrench.

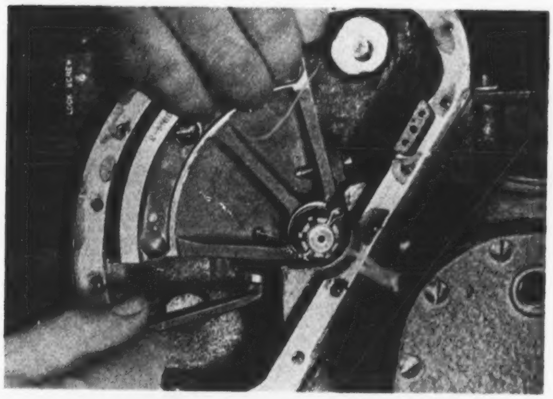
27. Now find the coupling on the deflection shaft between the stop block and the worm shaft. Remove the cotter pin from this coupling. Slide the worm shaft and its bearing to the right, until the bearing is free. Then very lightly tap the bearing with a mallet, to free it from the shaft. (Note: This must be done before the worm shaft will clear the access hole.) Now withdraw the worm shaft through the hole in the telescope body, sliding off the bearing as you withdraw the shaft. Be careful not to damage the worm threads during withdrawal.

28. Remove the three screws (shown in fig. 12-30) from the deflection prism mount housing while supporting the mount with your hand.

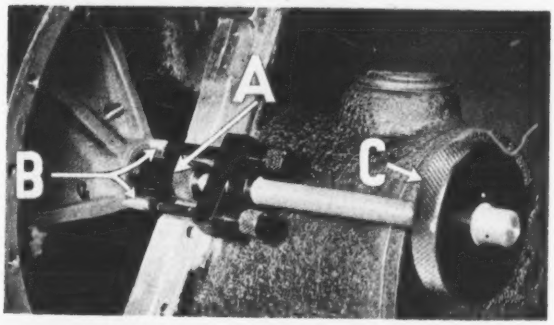
29. Pull the housing out of the telescope body very carefully. (CAUTION: As you do this step, watch for three shim type, washer shaped spacers, one each around each screw hole. These washers must be reassembled in their original positions. Gage the washers for thickness, and store them in marked envelopes. (See figure 12-31.)

30. Remove the setscrew that locks the optical tube retaining ring (fig. 12-32). This ring and the optical tube setscrew are located through the deflection prism flange.

31. With the special wrench shown in figure 12-33, reach through the hole in the end of



148.155
Figure 12-19.—Releasing the segment counterbalance.



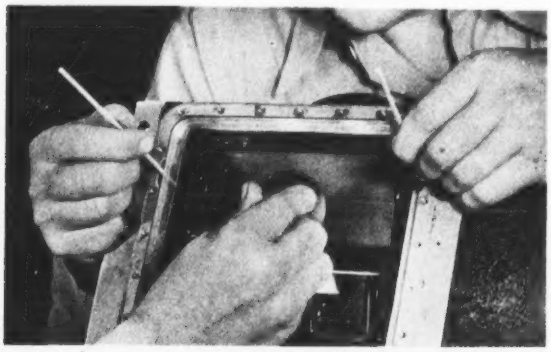
148.156
Figure 12-20.—Pulling the gear segment.

of the body, and loosen the optical tube retaining ring. Unscrew the ring, and remove it.

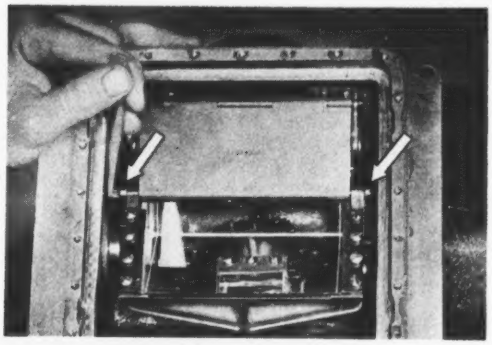
32. Remove the optical tube setscrew. It is just to the left of the retaining ring setscrew.) Carefully withdraw the optical tube through the opening in the end of the telescope body. Put it in a safe place.

33. Remove the 11 screws from the color filter mount. Lift the whole color filter assembly off the body.

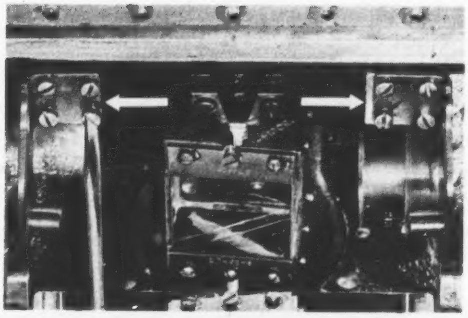
34. Remove the lock screw from the eyepiece mount (fig. 12-34). Unscrew the eyepiece mount, and remove it.



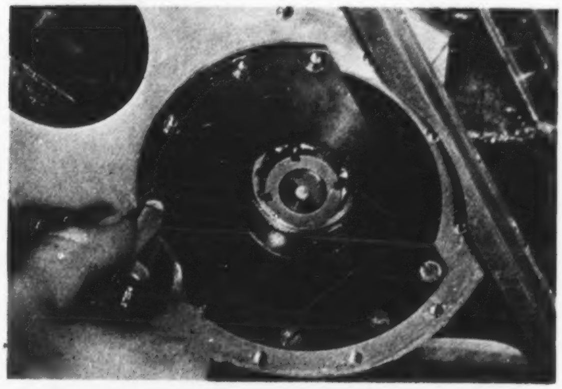
148.157
Figure 12-21.—Removing the objective window.



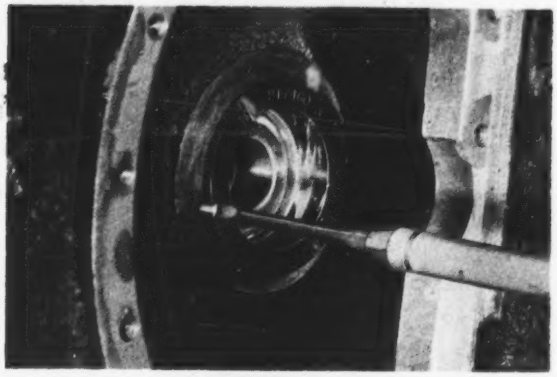
148.158
Figure 12-22.—Removing the shutter mount screws.



148.159
Figure 12-23.—Removing the shutter guides.



148.160
Figure 12-24.—Releasing the head prism bearing bracket.

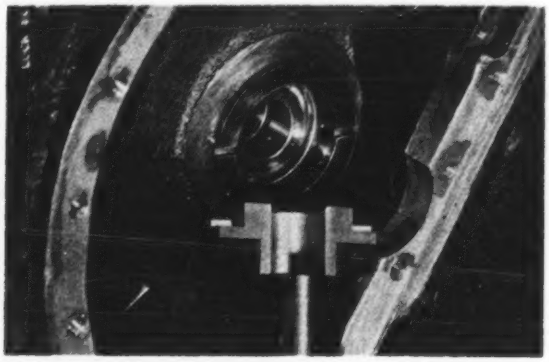


148.161
Figure 12-25.—Removing the thrust bearing retainer lock screw.

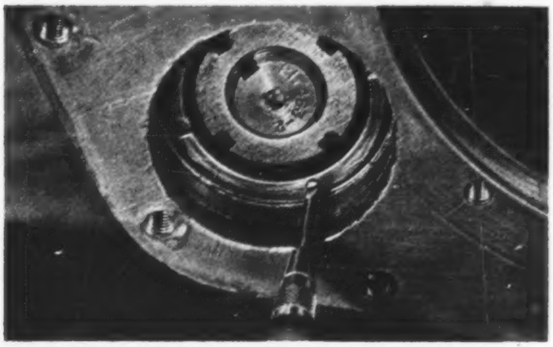
35. In the telescope body, under the eyepiece mount, you will find a diaphragm ring. Unscrew and remove it. That will expose the sealing glass retaining ring. Remove it.

36. With a small scriber, pry out the brass ring from the lead seal around the sealing glass. Then pry out the lead seal, being careful not to scratch the sealing glass. Lift out the glass with a suction cup.

37. Remove the 10 screws from the square cover over the roof prism mount. Lift off the cover. The six screws shown in figure 12-35 secure the prism mount to the body. Remove these screws, and withdraw the prism mount.



148.161
Figure 12-26.—Thrust bearing retainer ring wrench.



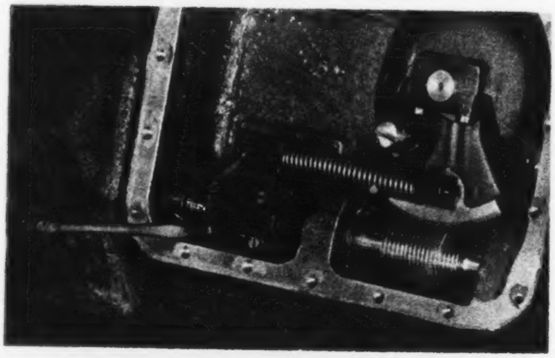
148.163
Figure 12-27.—Removing the worm shaft bearing retainer screw.

38. Use the special spanner wrench shown in figure 12-36 to loosen the lock nut on the rear erecting lens mount. Reach in through the color filter opening, back off the nut, and remove it.

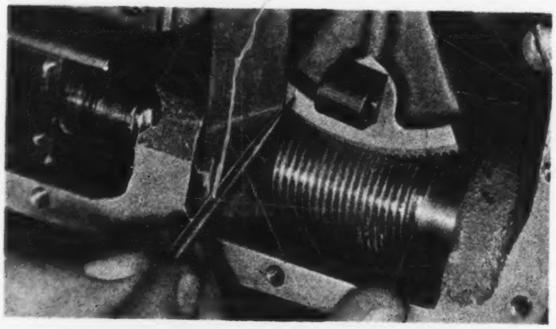
39. Reach in through the eyepiece prism opening, unscrew the rear erector mount, and remove it.

40. Now go back to the prism end of the deflection shaft. Remove the three screws (shown in fig. 12-37) from the stop block guide bracket. Lift off the bracket.

41. Use a heavy screwdriver as a lever (as in fig. 12-38) to move the stop block coupling and collars along the shaft. As you pull the stop block assembly off the shaft,



148.164
Figure 12-28.—Releasing the plunger arm, plunger, and spring.



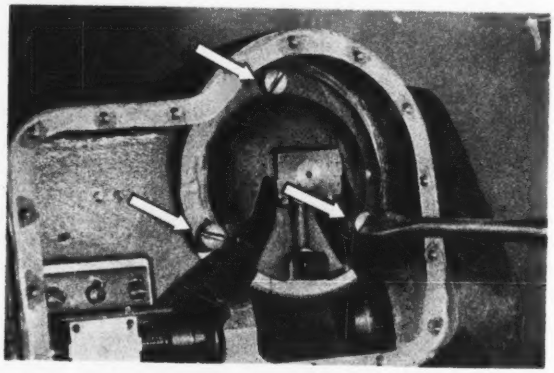
148.165
Figure 12-. . —Marking the gear segment.

run the block up to the stop on the collar which is closest to the eyepiece, so it will clear the end of the shaft. (To see how the coupling works, refer to fig. 12-52.)

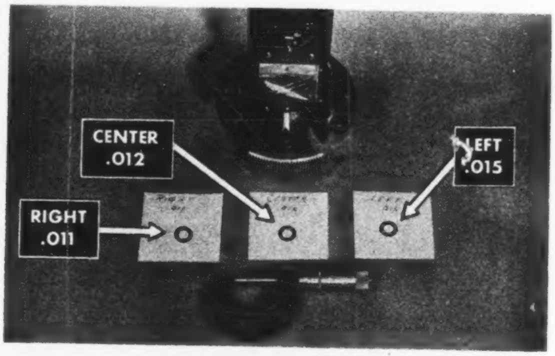
42. Remove 10 screws from the deflection gear cover (fig. 12-39), and remove the cover. Use the special wrench shown in figure 12-40 to remove the deflection input shaft cap. Remove the packing gland (it is locked by a small setscrew).

43. The lock nut on the end of the deflection input shaft is secured by a lock washer, with one of its points bent up into a slot in the nut. Use a punch and hammer to knock down the washer point and free the nut. Remove the nut with the special wrench provided for it, and lift off the washer.

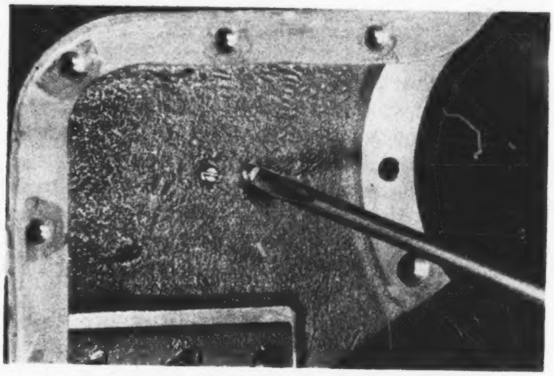
44. Remove two screws from the deflection index (fig. 12-41), and lift off the index. Remove



148.166
Figure 12-30.—Deflection prism mount screws.



148.167
Figure 12-31.—Deflection prism housing shims.



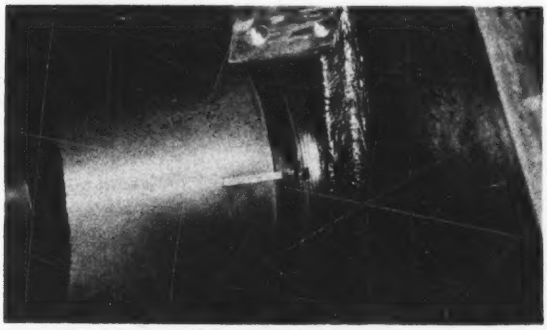
148.168
Figure 12-32.—Removing the optical tube retainer setscrew.

two screws from the pointer (fig. 12-42). Note: Make sure that both pinion gears are marked (see fig. 12-49).

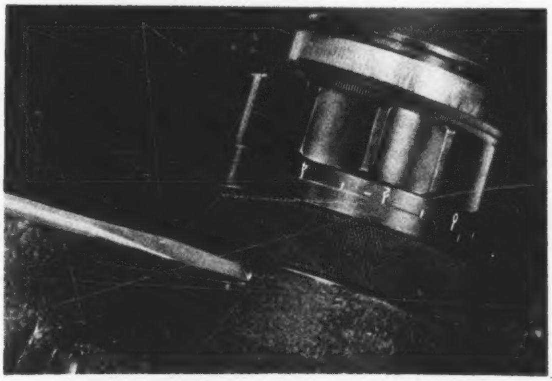
45. Drive the tapered pin from the input shaft pinion gear. (Fig. 12-43.) Remove the small lock screw that secures the retaining ring on the input shaft bearing (fig. 12-44). Remove the retaining ring.

46. Tap the shaft lightly with a mallet to remove the upper bearing and pointer (fig. 12-45). Pull out the shaft with its lower bearing still in place. Support the pinion gear with your other hand, so it will not fall.

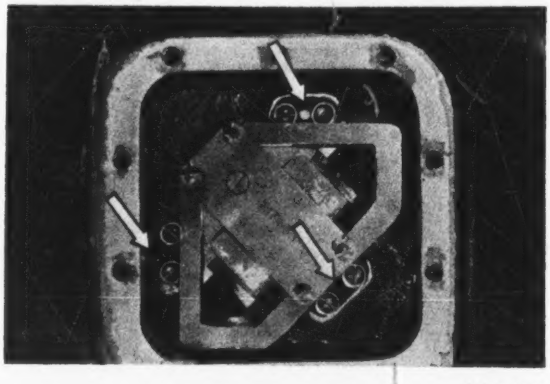
47. Remove the gear from the deflection shaft, using the gear puller shown in figure 12-46. Fit the small cap over the end of the shaft. Insert the two screws in the threaded holes on the gear. Pull the gear by turning the large knurled knob clockwise.



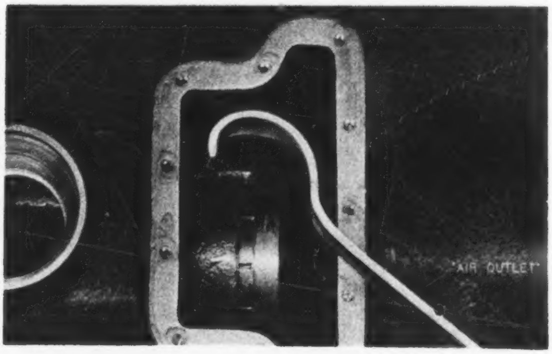
148.169
Figure 12-33.—Removing the optical tube retaining ring.



148.170
Figure 12-34.—Removing the eyepiece mount lock screw.



148.171
Figure 12-35.—Eyepiece prism mount screws.

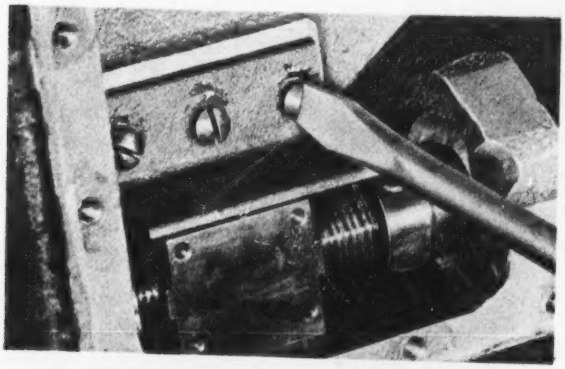


148.172
Figure 12-36.—Erecting lens mount spanner wrench.

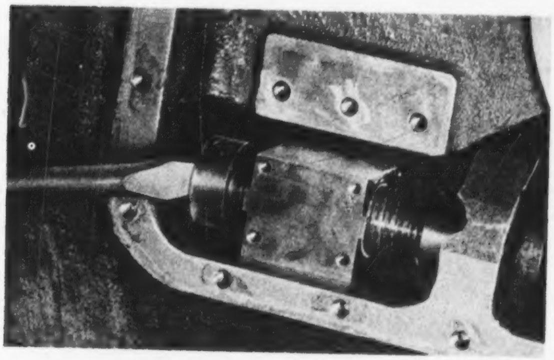
48. Pulling the gear will expose the retaining ring on the deflection shaft bearing. Remove the ring with the special wrench provided for it. Now withdraw the shaft through the opening in the end of the body.

49. Now you are ready to start on the subassemblies. Begin with the inner optical tube. Remove the small lock screw from its retaining ring (fig. 12-47). Back off the retaining ring with a fiber grip wrench.

50. Find the small lock screw near the middle of the optical tube, and remove it. Now withdraw the inner optical tube, which contains the crossline lens and the front erecting lens.



148.173
Figure 12-37.—Removing the stop block guide bracket.



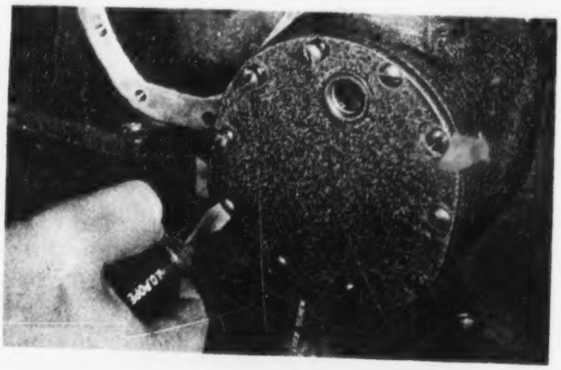
148.174
Figure 12-38.—Moving the coupling and collars.

51. From the other end of the optical tube, remove the objective mount lock ring with a fiber grip wrench. Unscrew the objective mount, and remove it. Protect the objective with a rubber washer, and remove its ring with an adjustable slot wrench. Remove the objective, and mark it to show the path of light through it.

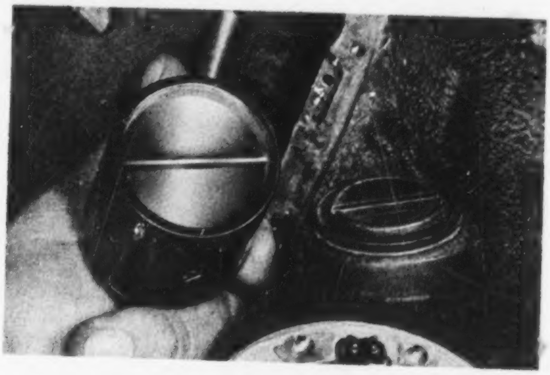
52. Disassemble the eyepiece, the inner optical tube, and the rear erecting lens mount. If necessary, disassemble the color filter assembly and the eyepiece prism mount.

CASUALTY ANALYSIS

Inspect all parts after disassembly and analyze casualties; functional defects listed on the job order should be included in this inspection. When you find the trouble, record it on the casualty analysis sheet.



148.175
Figure 12-39.—Removing the deflection gear cover.



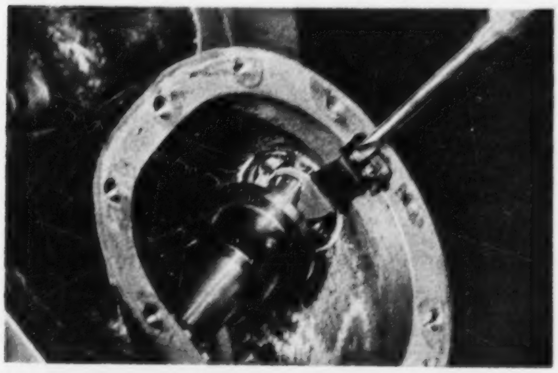
148.176
Figure 12-40.—Deflection input cap wrench.

When checking optical parts there are three main defects to look for:

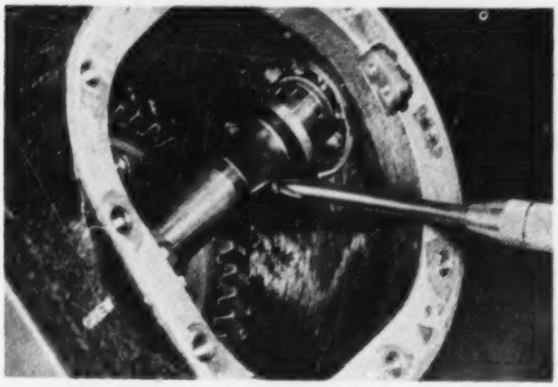
1. Check the antireflection coating on the surfaces of the lenses.
2. Inspect the condition of the cement between the lenses.
3. Check the lenses for chips and scratches. Record your findings on the casualty analysis sheet.

Checking optical parts is only half of the casualty analysis. Inspect the mechanical parts next. Some common discrepancies are:

1. Burrs, dents, distortion, damaged threads, and wear.
2. Appearance and finish defects.



148.177
Figure 12-41.—Removing the deflection index.



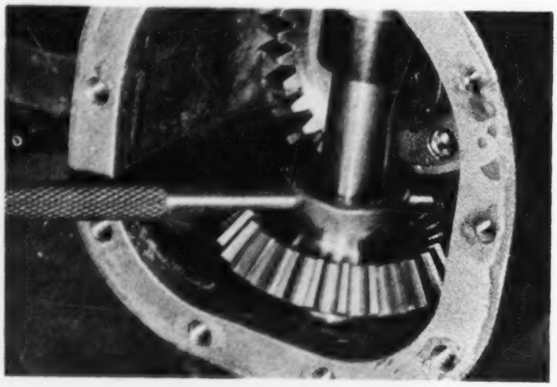
148.178
Figure 12-42.—Removing the screws from the pointer.

Repair parts only when the repairs are economically feasible, otherwise replace with new parts.

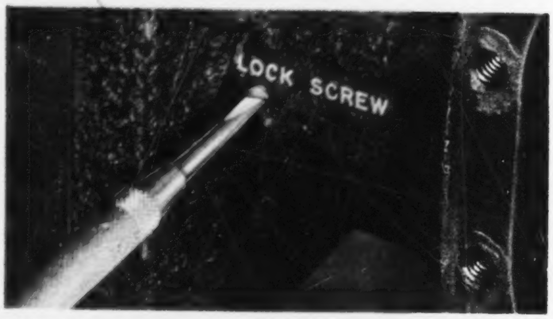
REASSEMBLY

In reassembly refer back to the illustrations used in the disassembly procedure when needed. (Note: Use new gaskets throughout when reassembling any optical instrument.) Follow these steps:

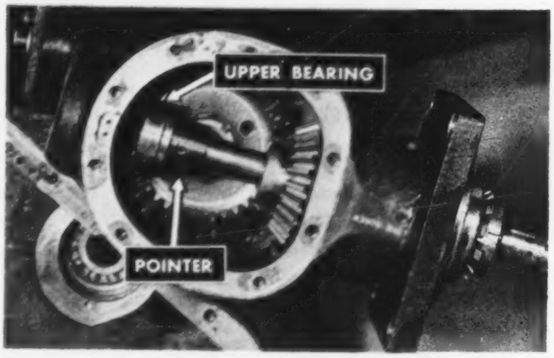
1. Reassemble the eyepiece by replacing the focusing key, the focusing ring, and the focusing retaining ring. Replace the two eyepiece lenses and their spacer, and secure them with the retaining ring. Replace the eyepiece



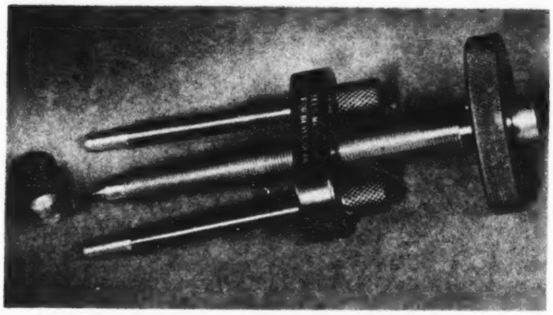
148.179
Figure 12-43.—Removing the tapered pin from the pinion gear.



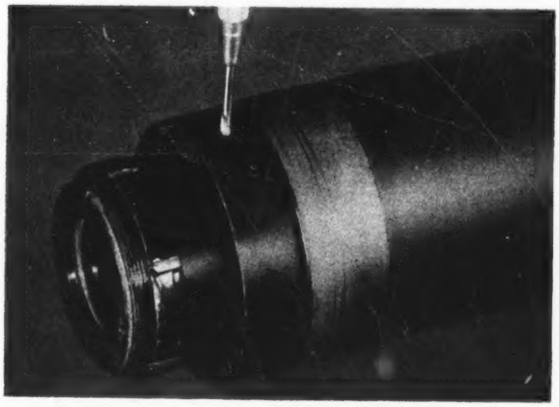
148.180
Figure 12-44.—Removing the retaining ring lock screw.



148.181
Figure 12-45.—Removing the upper bearing and pointer.



148.182
Figure 12-46.—Gear puller.



148.183
Figure 12-47.—Removing the inner optical tube retainer lock screw.

prism in its mount, if you have removed it. Replace the objective and the erectors in their mounts.

2. Insert the deflection shaft through the hole in the end of the body. Reach down through the color filter opening to guide the shaft through its center bearing. When the shaft is in place, screw in the bearing retaining ring. Tighten it with the special wrench, and secure it with its setscrew.

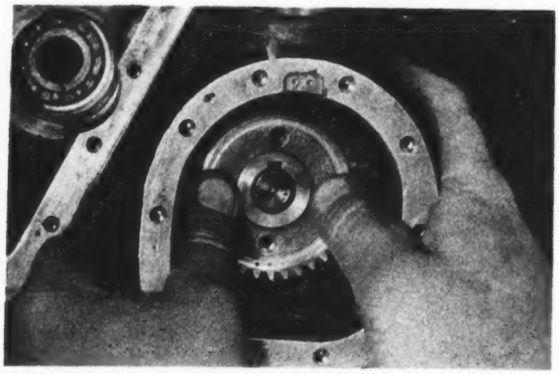
3. Push the deflection gear onto the shaft (fig. 12-48). Use equal pressure on both sides of the gear. Fit the slot in the gear over the key on the shaft. Screw the lock washer and nut onto the end of the shaft. Secure the nut by bending one of the points of the lock washer up into a slot on the nut.

4. Insert the input shaft through the pinion gear. There are punch pricks on both the bevel and the pinion gear (fig. 12-49). Line them up as you insert the input shaft.

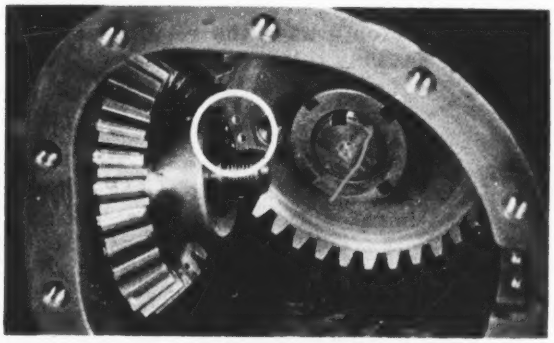
5. Slip the pointer onto the shaft. Notice the two small holes into which the pointer setscrews will fit. Now push the shaft on through. Lubricate the upper bearing, and slip it over the end of the shaft.

6. Secure the pinion gear to the shaft by hammering in the tapered pin. Do NOT hit the gear teeth.

7. Align the setscrew holes of the pointer with the two small holes spotted in the shaft. Replace the pointer setscrews, and tighten



148.184
Figure 12-48.—Replacing the deflection gear.



148.185
Figure 12-49.—Aligning the bevel and pinion gears.

them. Replace the deflection index, and secure it with its two screws.

8. Replace the deflection bearing lock ring, and tighten it with its special wrench. Secure the bearing lock ring by replacing and tightening its lock screw.

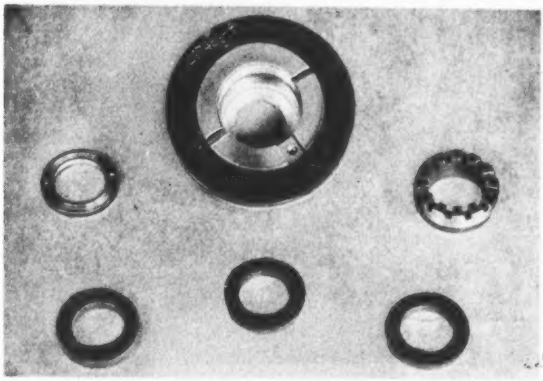
9. Replace the lock nut and washer on the deflection input shaft, above the upper bearing. Secure the nut by bending a point of the washer up into one of the slots.

10. Disassemble the packing gland by removing the retaining ring. (The ring is locked by a small retainer lug. Remove the lug first.) Figure 12-50 shows the parts: the gland, the retaining ring, a brass spacer, and three packing rings.

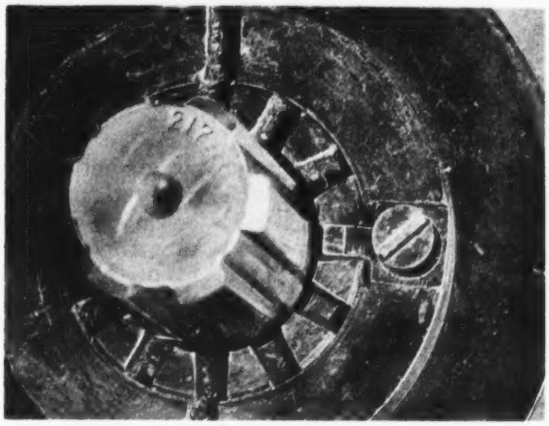
11. Fit a new Koroseal gasket, 1/32-inch thick, to the gland. Slip the gland over the shaft, screw it in, and tighten it securely. Now cut out three new packing rings of "Hycar." Do not use any substitutes. Fit the three new packing rings onto the shaft, and push them up into the gland. Put the brass spacer, then the retaining ring, on the shaft. Tighten the retaining ring until you can no longer turn the shaft easily with your fingers. Secure the retaining ring with the brass retainer lug (fig. 12 -51).

12. Screw on the shaft cap, and tighten it with its special wrench.

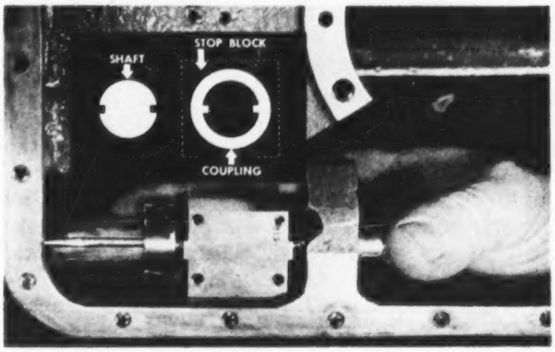
13. Replace the stop block coupling. Fit the keys on the stop block coupling into the slots on the shaft. (The insert in fig. 12-52 shows a cross section.)



148.186
Figure 12-50.—Packing gland, disassembled.



148.187
Figure 12-51.—The retainer lug.



148.188
Figure 12-52.—Replacing the stop block.

14. Lubricate the bearing surface of the stop block guide bracket. Replace the bearing over the block, and secure it with three screws.

15. Replace the objective mount in the optical tube. Reassemble the inner optical tube (containing the cross line lens and the front erector). Now you will have to make the first of many collimation steps which are required throughout the reassembly of this instrument. This first step is the squaring of the cross line in the inner tube. You will make the final small adjustment to square the cross line to the collimator while the instrument is being given the final collimation on the collimator.

a. Place the inner optical tube on V-blocks that are setting on a flat surface such as a collimator table, making sure that the cross line is facing you.

b. Set a small machinist's square on the table and align the blade of the square in the illumination slot, making sure that the blade is flush against the bottom of the slot.

c. Set the protractor head of a combination square, with the scale fully extended, at 125° (vertical plane 90° plus 35° eyepiece offset).

d. With the protractor head setting on the table, pass the scale in front of the optical tube until the scale edge superimposes on the center of the cross line. Now carefully take a scribe and scribe two marks on the end edges of the inner optical tube at the point where the protractor scale meets this surface.

(When you reassemble the cross line to previously scribed lines you may find that upon moving the protractor head so that the scale superimposes on the cross line center, the cross line is superimposed perfectly with the edge of the scale along its entire length. If this is so you will NOT have to make any further adjustments of the cross line in the inner optical tube.)

e. If the cross line does not line up with the scale, then it will be necessary to loosen the cross line retainer ring, and using the scribe marks on the edge of the tube as a reference, rotate the cross line carefully until it is aligned with the scribe marks; then retighten the retainer ring.

(With the cross line facing you, the scale of the protractor will point to your left for a Mark 67, and to your right for a Mark 68 telescope.)

16. Mount the inner optical tube on the collimator. Sight the cross lines through an auxiliary eyepiece (fig. 12-53).

17. You will see two sets of cross lines: those in the optical tube and those in the collimator. Screw the front erector lens in or out until both cross lines are sharp. (They do not have to superimpose.)

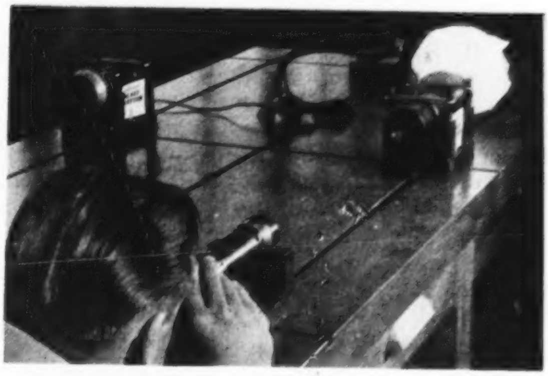
18. Now line up the inner optical tube in the optical tube. Sight through the setscrew hole, and line up the small hole in the inner tube. Replace the setscrew, and tighten it. Replace the inner tube retaining ring, and tighten it with a fiber wrench. Secure it with its lock screw.

19. Set up the complete optical tube on the collimator, and sight through it with an auxiliary telescope. Remove parallax by screwing the objective mount in or out. Secure the adjustment by tightening the objective mount retaining ring.

20. Remove the four screws from the cross line illuminator housing (fig. 12-54), and lift off the housing.

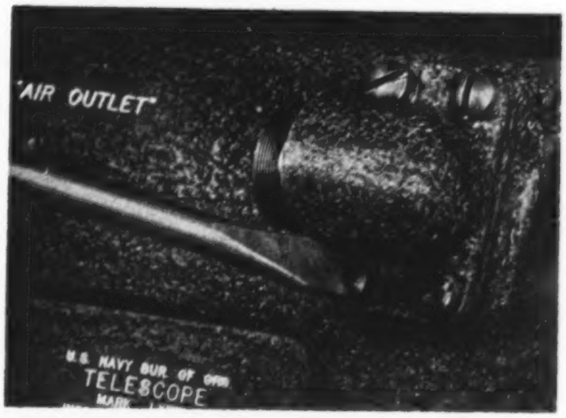
21. Insert the optical tube through the opening in the telescope body. Sight down through the illuminator sealing window to line up the slot through which the cross line lens is illuminated (fig. 12-55).

22. When you get the optical tube properly lined up, secure it by replacing and lightly tightening its setscrew (fig. 12-56). Replace



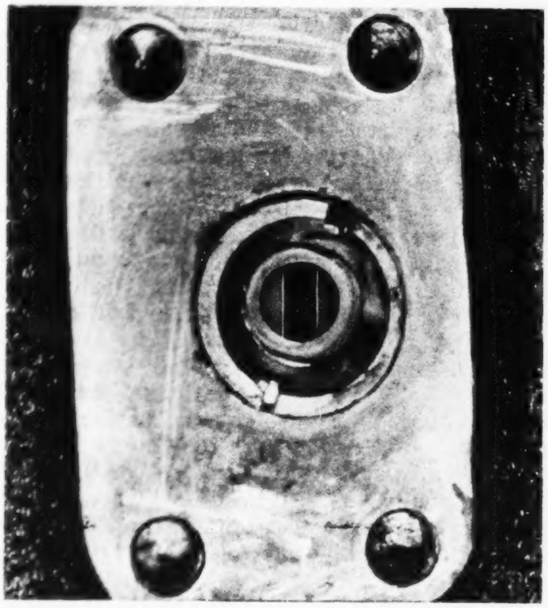
148.189

Figure 12-53.—Collimating the inner optical tube.

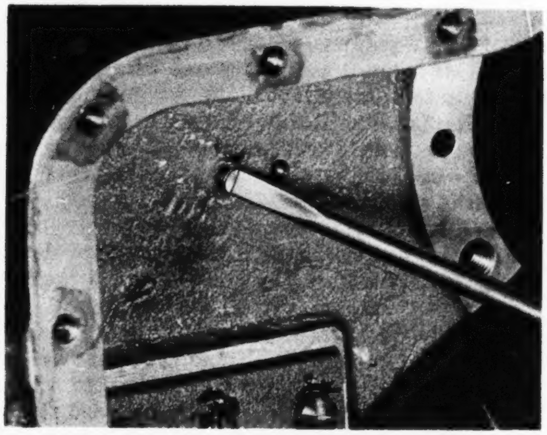


148.190

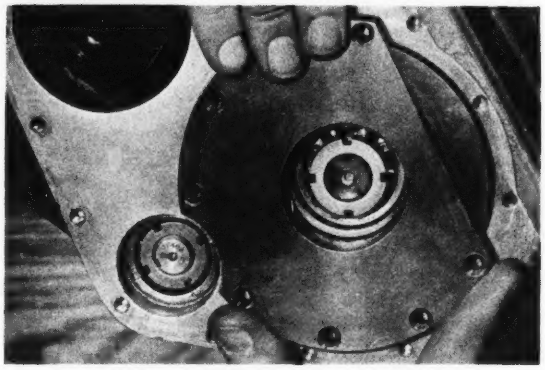
Figure 12-54.—Removing the illuminator housing.



148.191
Figure 12-55.—Lining up the illuminating slot.



148.192
Figure 12-56.—Replacing the optical tube setscrew.



148.193
Figure 12-57.—Replacing the elevating shaft bearing bracket.

the optical tube retaining ring, and tighten it lightly with its special wrench. Replace and tighten the retaining ring setscrew lightly. It goes just to the right of the optical tube setscrew. (Note: The adjustments just described are made lightly so that the outer optical tube may be rotated to square the scope cross line to the collimator cross line later in the final collimation step.)

23. Now get out the three shims (washers) for the deflection prism housing. Put them in their proper positions. Carefully guide the deflection prism housing into place without disturbing the shims. Replace and tighten the three screws that secure the housing to the telescope body. (Note: The deflection prism will have to be removed after the scope cross line is squared to the collimator to facilitate tightening the outer optical tube lock ring; thus the lock ring must be secured just tight enough to hold the cross line snugly in place.)

24. Insert the elevating prism and its shaft through the opening in the telescope body.

25. Replace the elevating shaft bearing bracket (fig. 12-57). Secure it with its eight screws.

26. Slip the two thrust bearings, with their separator between them, over the end of the shaft. Replace the retaining ring, and tighten it with the special cutaway wrench. Secure the ring with its lock screw.

27. Replace the key in the slot of the elevating shaft. Fit the elevation gear segment over the shaft, making sure to line up the key and keyway. Secure the segment with its lock nut, and replace the cotter pin through the nut.

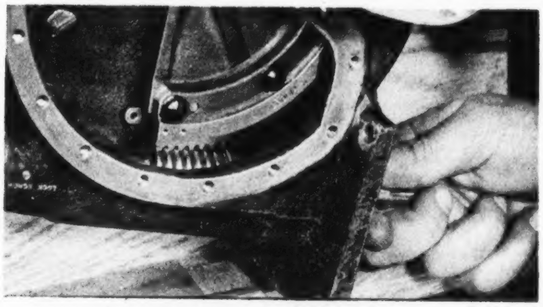
28. With the gear segment resting against its lower stop (fig. 12-58), insert the elevation input shaft, and push it into place. Replace

the two bearings, with their separator between them, over the end of the shaft. Replace the lock washer and nut on the shaft, and secure the nut by bending one of the washer points up into one of the slots.

29. Replace the thrust bearing retaining ring, tighten it with its special tool, and secure it with its lock screw. Replace the cap, and tighten it with its special wrench.

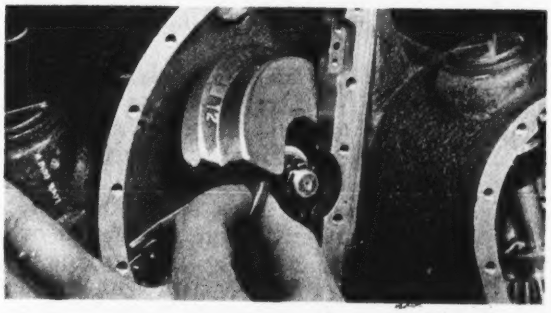
30. Run the gear segment down to its lower stop, so you can fit the sector counterbalance around the shaft (fig. 12-59). Secure the upper screw with an offset screwdriver. Then replace and tighten the lower screw.

31. Now reassemble the antibacklash group. First, hook the steel strap over a pin on the drum, and roll it up. Insert the drum and its shaft by slipping one end of the shaft into the bearing hole in the body. Mount the drum shaft support over the other end of the shaft, and secure it with four screws.



148.194

Figure 12-58.—Replacing the elevation input shaft.



148.195

Figure 12-59.—Replacing the segment counterbalance.

32. Secure the free end of the strap, by its pin, to the strap arm. Fasten the strap arm to the gear segment with two screws.

33. Wind up the drum with a screwdriver, holding the drum with the adjusting pin while you move the screwdriver to a new slot. Replace the adjusting pin when you think you have the proper tension. If necessary, you can change the tension during collimation.

34. Reach through the eyepiece prism opening and screw the rear erecting lens mount into place. You will adjust it during collimation.

35. Put a gasket of Koroseal, 1/32-inch thick, under the eyepiece sealing window, and replace the window. Form a lead and brass gasket around it. (Refer to chapter 12 of Opticalman 3 & 2, NavPers 10205.)

36. Replace the retaining ring over the glass, and tighten it. Screw in the diaphragm, and tighten it with its special tool. Screw the eyepiece assembly into place, and secure it with its lock screw.

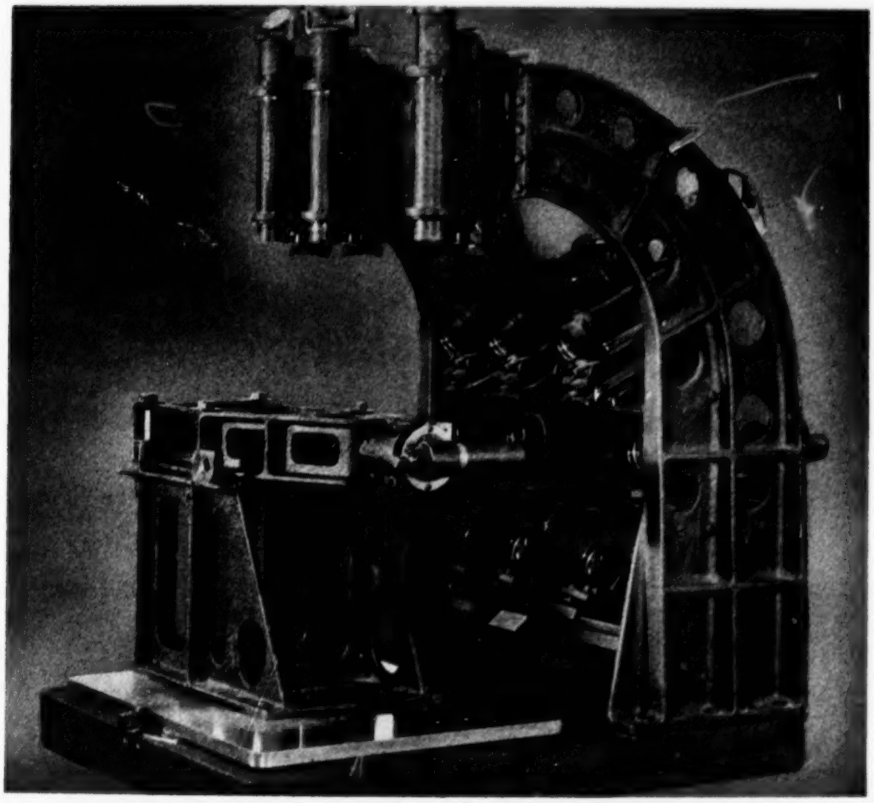
37. Insert the eyepiece prism mount through its opening in the telescope body, and secure it in place with six screws.

38. Now you are ready to collimate. Figure 12-60 shows the Mark 6 collimator, with the fixture for the Mark 67-68 telescopes in place. Figure 12-61 is a closeup of the checking telescope Mark 16 and its support fixture, which you will use to line up the telescopes of the collimator. (Note: OP 1417 may be referred to for greater detail on these fixtures.)

39. Set the collimator base vernier index at zero. Use the checking telescope to align the horizontal collimator telescope with the fixture (fig. 12-62). Now align the 90° collimator tube (fig. 12-63).

40. Clean the bearing surfaces of the telescope and the collimator fixture. Mount the telescope on the fixture, and bolt it securely into place.

41. Set the eyepiece diopter scale at zero. Sight through the eyepiece with an auxiliary telescope, which is set to the repairman's individual eye correction, and check the focus of the cross lines. If they are not sharp, reach in through the color filter opening and adjust the rear erecting lens mount until they are. (Be sure the eyepiece diopter scale stays at zero.) Then, with the special spanner wrench, tighten the lock ring in the rear erector lens mount.



148.196

Figure 12-60.—The Mark 6 collimator.

42. Now sight through the eyepiece, and superimpose the telescope cross lines on the 0° elevation collimator telescope by operating the elevation input shaft and moving the deflection prism by hand. (Remember that the deflection worm shaft HAS NOT been reassembled in the scope yet.) The vertical cross line of the telescope must not be off the vertical cross line of the collimator by more than 1 minute. If the cross line is NOT square, rotate the outer optical tube until the cross line is exactly square with the collimator cross line. Then secure the outer optical tube setscrew, remove the lightly secured deflection prism mount and tighten the outer optical tube lock ring and its setscrew. Replace the deflection prism and recheck cross line squareness.

43. Lubricate the deflection worm shaft bearing, and slip it into place (fig. 12-64). Insert the worm gear segment (fig. 12-65). When the stop block is centered, the first thread of the worm gear must line up with the scribe mark. Insert a cotter pin to link the worm shaft to the coupling.

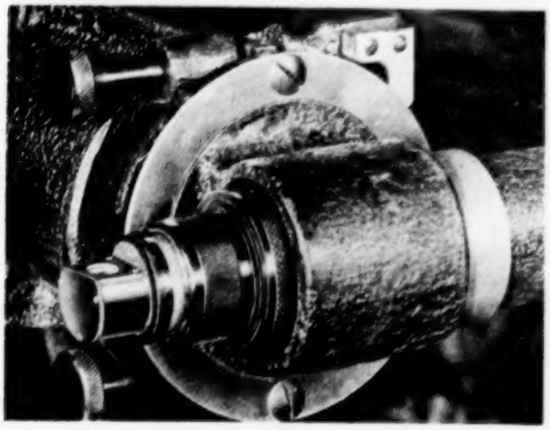
44. Insert the plunger in the eye of the segment (fig. 12-66). Fasten the plunger arm to the stop block with its four screws.

45. Insert the deflection worm bearing lock ring, and tighten it, secure it with its setscrew.

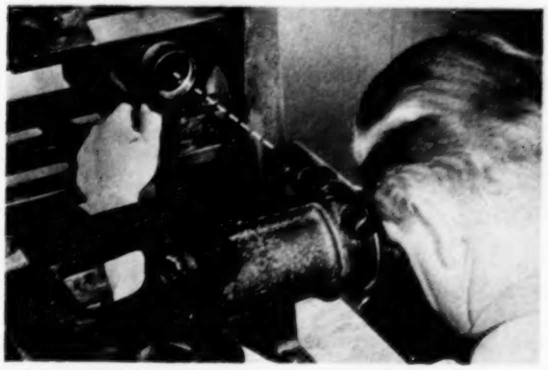
46. Check for backlash in the deflection mechanism. First, rotate the deflection shaft to bring the pointer to the left of the index (fig. 12-67).

47. Now bring the pointer back on the index, using an eye loupe to check the alignment. Sight the vertical cross lines again. The vertical cross line of the telescope must not have moved more than 30 seconds from its original

176



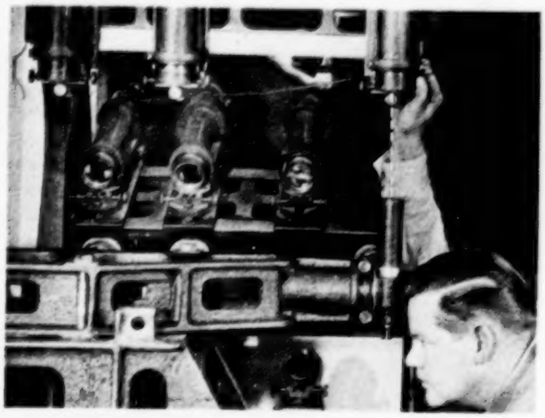
148.197
Figure 12-61.—The Mark 16 checking telescope.



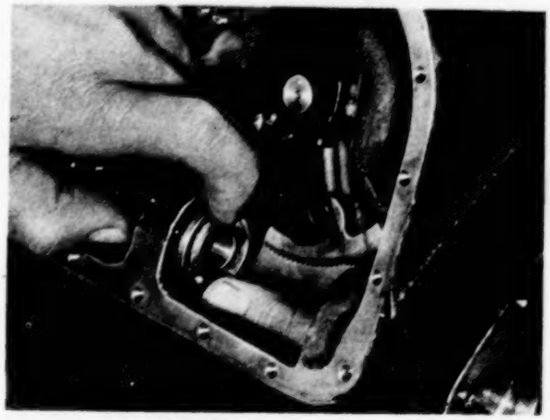
148.198
Figure 12-62.—Aligning the horizontal collimater telescope.

position. Displace the pointer to the right, bring it back to the index, and check again. The vertical cross line must still be within 30 seconds of its original position. If it is off by more than 30 seconds on either test, there is too much backlash in the deflection mechanism. Either the plunger spring has insufficient tension, or the thrust bearings have been improperly replaced.

48. Slip a special collar with an indicating pointer over the end of the elevation input shaft gland (fig. 12-68). Mount the revolution-counting drum on the input shaft, and secure it with its lock screw (fig. 12-69).



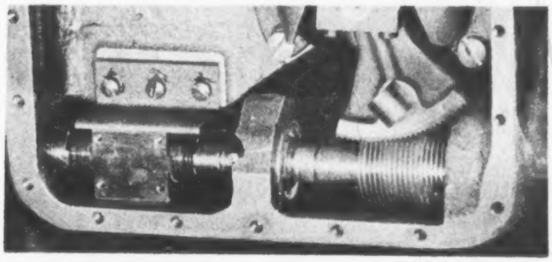
148.199
Figure 12-63.—Aligning the 90° collimator tube.



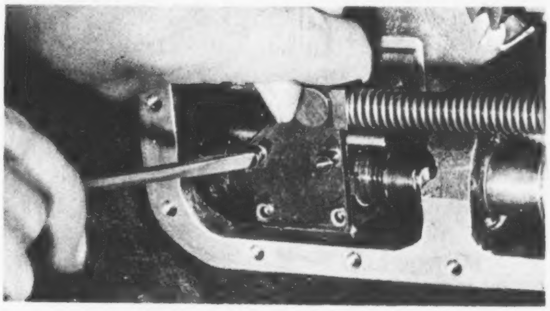
148.200
Figure 12-64.—Inserting the worm shaft.

49. Sight through the eyepiece, and turn the drum until the two horizontal cross lines coincide, utilizing the 0° elevation collimator telescope. Loosen the drum lock screw. Turn the drum (without turning the input shaft) to align the mark on the drum with the index mark on the pointer. Retighten the drum setscrew. Check the cross to be sure you did not turn the input shaft.

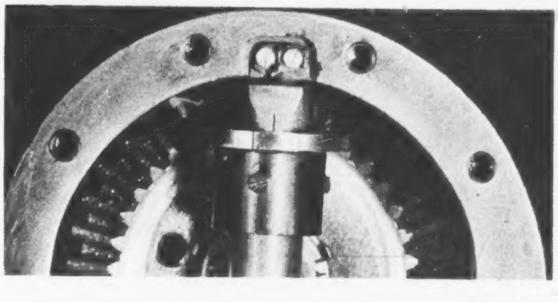
50. Elevate the line of sight 90° by turning the drum through exactly 13 1/2 revolutions. Sight through the telescope. The cross lines must coincide with those of the 90°



148.201
Figure 12-65.—Inserting the worm shaft.



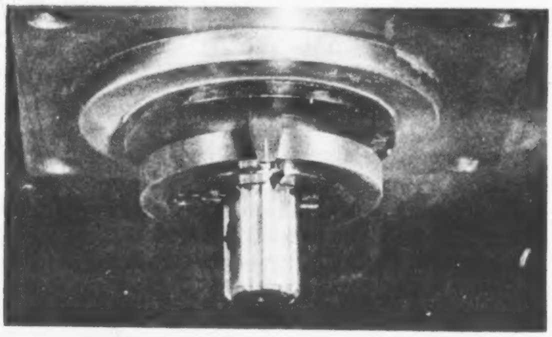
148.202
Figure 12-66.—Securing the plunger arm.



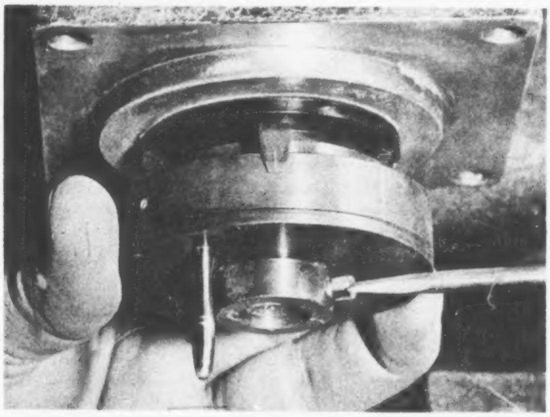
148.203
Figure 12-67.—Checking deflection backlash.

collimator telescope, with an error of not more than 2 minutes vertical or 3 minutes horizontal.

51. Now elevate all the way to the stop. This must take not more than one full additional turn. The horizontal cross line of the telescope must clear the graduations on the vertical cross line of the collimator.



148.204
Figure 12-68.—Special collar with index mark.



148.205
Figure 12-69.—Revolution counting drum.

52. Lower to 0° elevation, and line up the marks on the drum and pointer. Sight through the telescope. The horizontal cross line must not be more than 30 seconds off the horizontal cross line of the collimator. If it is off by more than that, there is too much backlash in the elevation mechanism. Increase the tension in the antibacklash drum, and check again.

53. Lower the line of sight as far as it will go. This must take not less than nine turns, and not more than ten turns of the input shaft. Raise the line of sight to 0°.

54. By rotating the input shafts, bring both the horizontal and the vertical cross lines of the scope and collimator into coincidence. Transfer your revolution counter to the deflection input shaft, and turn the shaft through

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exactly 3 1/3 turns counterclockwise. Remove the vernier adjustment screw block from the collimator, and rotate the telescope 20° to the left. (Check the aligment on the collimator scale with an eye loupe.)

55. Sight through the telescope. The horizontal cross lines must coincide, with an error of not more than ± 2 minutes.

56. Turn the deflection back to zero, and then turn the shaft exactly 3 1/3 turns clockwise. Swing the telescope back to zero deflection, and then 20° to the right. (Check the alignment of the collimator scale with your eye loupe.)

57. Repeat step 55. If the alignment is within tolerance, the telescope is properly collimated.

58. Complete your reassembly. Replace the two shutter guides, and secure them with four screws each. Place the shutter in the guide, and fasten it with the two screws, using an offset screwdriver.

59. Replace the front window, over a gasket of Koroseal. Fit a gasket of Coroprene over the window, and replace the window retainer. Replace and tighten the window retainer screws. IMPORTANT: Each screw in each retainer and sealing plate must be fitted with its own gasket of Koroseal.

60. Replace the illuminator housing, over a gasket of Koroseal.

61. Replace the color filter assembly, over a gasket of Coroprene. (Each screw has its own Koroseal gasket.)

62. Insert an illuminator, and check the cross line illumination. If it is satisfactory, replace all the sealing plates. (Read the section on sealing, in chapter 8 of Opticalman 3 & 2, NavPers 10205.)

SEALING, DRYING AND CHARGING

1. Charge the telescope with dry nitrogen, to a pressure of 8 pounds. This is the maximum safe limit to test this telescope. (Read the section on charging, in chapter 8 of Opticalman 3 & 2, NavPers 10205.)
2. Test the telescope for leaks by submerging it in water. If no bubbles appear, remove the telescope, dry it, and bleed the pressure to 4 pounds.
3. Replace the window wiper attachment, and its side strips.
4. Replace the motor unit, and bolt it into place.
5. Connect the flexible cable from the wiper attachment to the motor.

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APPENDIX 1

TRAINING FILM LIST

Certain training films that are directly related to the information presented in this training course are listed below under appropriate chapter numbers and titles. Unless otherwise specified, all films listed are black and white with sound, and are unclassified. For a description of these and other training films that may be of interested, see the United States Navy Film Catalog, NavWeps 10-1-777.

Chapter 1

ADVANCEMENT

MN-06798D	Your Job in the Navy—Part 4. (31 min.—1950.)

Chapter 3

METALS

ME-07313A	Heat Treatment of Aluminum—Part 1. (19 min.—1945.)
ME-07313C	Heat Treatment of Aluminum—Part 1. (24 min.—1945.)
ME-06885A	Heat Treatment of Steel—Elements of Hardening. (15 min.—1949.)
ME-06885B	Heat Treatment of Steel—Elements of Tempering, Normalizing, and Annealing. (22 min.—1949.)
ME-06885C	Heat Treatment of Steel—Elements of surface Hardening. (14 min.—1949.)

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